OCT 15 1943

JOURNAL *of* ECONOMIC ENTOMOLOGY

Published by

American Association of Economic Entomologists

at Menasha, Wisconsin

AUGUST · 1943

Volume 36 Number 4

JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ American Association of Economic Entomologists

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Published by

American Association of Economic Entomologists

at Menasha, Wisconsin

A bimonthly journal published on the 15th of February, April, June, August, October and December, devoted to the interests of economic entomology and publishing the official notices and proceedings of the American Association of Economic Entomologists.

TERMS OF SUBSCRIPTION. To members of the American Association of Economic Entomologists in continental U.S. and possessions, three dollars ($3.00) annually in advance; foreign members, three dollars fifty cents ($3.50). Non-members in the United States, Cuba, Mexico and Canada, four dollars ($4.00) annually in advance. Non-members elsewhere, four dollars fifty cents ($4.50). Single copies, seventy-five cents anywhere.

BUSINESS COMMUNICATIONS of the Association and SUBSCRIPTIONS AND ADVERTISEMENTS to the Journal should be sent to the business manager, E. N. Cory, 450 Ahnaip Street, Menasha, Wisconsin, or College Park, Maryland.

Entered as second class matter at the Post Office at Menasha, Wisconsin. Acceptance for mailing at special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph 4, Section 538, P. L. and R., authorized May 1, 1936.

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The Increase in Resistance in Insects to Insecticides

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One of the disturbing features of insect control is the apparent increase in resistance that may develop in some species to an insecticide that was previously satisfactory. Up to the present time, there seems to be sufficient experimental evidence to establish that fact in the case of seven species, and observation or circumstantial evidence tends to support such a contention in the case of some others.

The species for which experimental proof of incerased resistance has been presented include, in chronological order, (1) the San Jose scale, *Quadraspidiotus perniciosus* (Comst.), to the lime-sulfur spray (Melander 1914); (2) the California red scale, *Aonidiella aurantii* (Mask.), to HCN fumigation (Quayle 1916); (3) the black scale, *Saissetia oleae* (Bern.), to HCN fumigation (Quayle 1916); (4) the young larva of the codling moth, *Carpocapsa pomonella* (Linn) to arsenical and other sprays (Hough 1928); (5) the citricola scale, *Coccus pseudomagnoliarum* (Kuw.) to HCN fumigation (Quayle 1938); (6) the larva of the primary screw worm, *Cochliomyia americana* C&P to phenothiazine (Knipling 1942); and (7) the citrus thrips, *Scirtothrips citri* (Moult.), to tartar emetic-sucrose spray (Boyce *et al.*).

A review of the evidence in the literature cited supporting the proposition that an increased resistance in the insects mentioned has been shown need not be included here. Some of the more general historical aspects in each case will be discussed and following this a discussion of some other cases that are more speculative, for which experimental evidence is lacking, will be presented.

The question may still be open as to the most appropriate terms. "Resistant" and "resistance" were first used by Melander (1914) and Quayle (1916). "Tolerant" and "tolerance" have also been used and in some cases these terms may be more appropriate. Since both the adjective and noun of the terms need to be used, "resistant" and "resistance" appear preferable to "tolerant" and "tolerance." The former are also stronger terms and thus represent more accurately the response of most insects to insecticides, provided they are not used as synonymous with "immune" or "immunity."

The designation "increased resistance" in an insect species, as used in this paper, refers to the decreased effectiveness of the insecticide at the present time as compared with former years. In most cases the difference is still evident as between different localities or populations. Whether this change is due to a lower intake of the insecticide, a greater tolerance for the same amount of the insecticide, or whether actual repellency or lack of assimilation is involved as tentatively surmised in one case, is not here relevant. Since a particular species of insect, out of several for which the insecticide may be satisfactory, is in question and only certain populations or localities may be involved, it seems preferable to refer to the reaction of the insect rather than that of the insecticide.

The first insect listed, the San Jose scale, was introduced into the United States in California about 1870. Melander (1914, 1915, 1923) reports that it occurred in the state of Washington 30 years before he published his first paper on the subject of resistance to the lime-sulfur spray. The lime-sulfur spray was first used as an insecticide in the United States in California in 1880. Ten years later it was used generally in the state of Washington, where according to Piper (1903) it was "exceedingly effective on the San Jose scale." The spray had thus been used in Washington about 25 years before the claim of increased resistance was first published, although growers had complained of unsatisfactory results in a certain district

about 10 years previously. Increased resistance of the San Jose scale to the lime-sulfur spray was noted in Washington in one apple district only, the Clarkson. Thus it was possible to make comparisons of the relative effectiveness as as between districts over a number of years.

It should be noted at this point that there may be some objection to the claim that an increase in resistance in a particular locality has been shown in all cases by actual experimental evidence. When the San Jose scale was first subjected to experimentation, it had already shown a greater resistance in the Clarkson than in other apple districts of Washington. The experimental evidence proved that the scale was more resistant to lime-sulfur there than in other districts. But that previously the lime-sulfur spray was satisfactory must be left largely with commercial rather than experimental experience. In other cases that will be discussed, experimental as well as commercial evidence has shown that an actual increase in resistance in the same territory has occurred.

The lime-sulfur spray was the standard spray for the San Jose scale in California, Washington, and throughout the Eastern States for many years. In more recent years it has given way largely to petroleum oil sprays, which are now considered more effective. This may have been due to the gradual failure of the lime-sulfur spray or to the superior effectiveness of petroleum oil sprays from the beginning. Where the lime-sulfur spray is applied at the present time and the results on the scale are not satisfactory, it would appear that there is a difference as compared with the past. However, unsatisfactory results are reported at the present time where the use of lime-sulfur has been very limited or it may not have been used at all previously.

The next insect that was reported to exhibit an increased resistance to an insecticide which was effective for many years was the red scale (Quayle 1916, 1922, 1938; Moore 1933, 1936; Woglum 1925; Yust *et al.* 1942b). Hydrocyanic acid was an unusually effective insecticide from the time of its introduction to tree fumigation in 1886 to a few years previous to the first publication on the subject of its resistance, in 1916. And even at the present time HCN gives effective control over a large part of the red-scale-infested area in California. Like the San Jose scale, increased resistance to the insecticide appeared in a more or less definite locality. But the red scale has increased its resistance over a much greater area than was originally the case, and a difference in resistance can still be shown in California by making comparisons between insects from two different localities as well as between past and recent experience in the same locality. Whether such a fact can be shown in the case of the San Jose scale is problematical. And furthermore this insect, where treatment with lime-sulfur has been abandoned for many years, may have lost such resistance.

The red scale lends itself particularly well to experiments on the proof of resistance to an insecticide because in this case the insecticide is applied as a fumigant, where direct comparisons may be made with a readily diffusible gas within the same chamber. This insect may also be reared under controlled conditions on detached fruits which remain sound long enough to rear the insect to maturity plus two or three weeks after treatment when the results are determined (Lindgren 1938). Thus identical conditions of food and environment are maintained before, during and after the fumigation. The distribution of the resistant strain of red scale in southern California, while increasing, has been such as to make possible comparisons with the nonresistant strain for a period of nearly 30 years. Later experiments have indicated that similar differences in resistance in the red scale occur with two other fumigants, methyl bromide and ethylene dioxide. Yust & Busbey (1942) found this to be true of methyl bromide with respect to the same stage of the insect (adult female), but in a less marked degree than with HCN. With certain other stages of the insect similar results were not secured by these authors.

The screw worm larva recently reported upon (Knipling 1942) represents a type of insect that is also particularly adapted to resistance studies. This has suggested the possibility also of utilizing the classic *Drosophila* in such a role, and this insect is now being tested in this laboratory as to its availability for such a study. The adult has already been used in connection with resistance studies with HCN fumigation (Boyce 1928). When the insecticide may

be incorporated in a suitable medium in which the organism can live and from which it obtains its food, as in the case of the screw worm larva, a simple procedure is provided because there may be no variable factors aside from the insecticide incorporated in the medium, and as has been demonstrated by the work of the Melvin & Bushland (1940), Bushland (1940), and Knipling (1942). This constitutes an additional procedure for determining resistance. The list of insects and the types of insecticides to which they have developed resistance are as follows: the San Jose scale, a sucking insect, to a contact spray; the red, black, and citricola scales, sucking insects, to a fumigant; the young codling-moth larva, a biting insect, to a stomach poison; the larva of the primary screw worm, living within the medium from which it obtains its food, to, presumably, a stomach poison incorporated in the same medium; and the citrus thrips, with sucking and rasping mouth parts, to a poison bait spray.

Resuming the discussion of the red scale, Dickson (1941) has shown how the factor of resistance is inherited in this insect. It depends on a single gene (or a group of closely linked genes) in the X-chromosome and is therefore sex-linked. Crosses were made between the resistant and nonresistant strains and the F_1 progeny were intermediate in survival to HCN between the two parental strains. Whether the gene for resistance was originally introduced into the locality where resistance was first observed or whether it arose by mutation is not possible to say. The writer agrees with Dobzhansky (1941) that more probably it arose by mutation. While the progressive occurrence of resistance in different localities lends some weight to a spread from the original location in California, the writer believes that, at least in some cases, additional mutations were responsible. Stronger support of this fact will be brought out in connection with the citricola scale and the citrus thrips.

Colonies of resistant and nonresistant red scale have been separately maintained under identical conditions at Riverside for a period of seven years, during which time there have been 60 generations. The same differential in resistance between the two strains to HCN has been shown continuously throughout this period. Studies are being continued to determine if resistance may be increased in both the resistant and the nonresistant strains by repeated fumigations.

Physiological differences have been shown to occur between the resistant and nonresistant red scales. The particular stage of the insect in the resistant strain that is most resistant to HCN fumigation is during the period of the second molt (Quayle 1922, Lindgren 1941), while the nonresistant strain is most resistant just following the second molt or early gray stage (Lindgren 1941). Response to a sublethal or stupefying dosage, applied before the regular dosage of HCN, is also different in the two strains (Lindgren 1938; Yust *et al.*, 1942a). Observable differences in the action of the spiracles in the two strains have also been shown (Hardman & Craig, 1941).

The mechanism of resistance has not been definitely shown but it appears to be due to the inherent resistance within the organism itself rather than a difference in the protection afforded by the waxy covering, or by a difference in the action of the spiracles. The fact that resistance has been shown in all stages of the insect, including the motile young (Lindgren 1941) which has no covering, would rule out the covering; and fumigation experience does not appear to support, at least entirely, the difference in spiracular behavior (Quayle 1942).

Resistance to HCN in the black scale in California has much the same history as that of the California red scale (Quayle 1916, 1922, 1938), (Woglum 1925), (Gray & Kirkpatrick 1929b). Evidence of the fact appeared at about the same time and in the same period of years after the insecticide was first employed. The present location where the black scale is resistant represents a more compact area than the widely scattered areas where the red scale is resistant. The main well-established black scale area at the present has not extended much beyond a radius of 20 or 30 miles from the center where it was originally determined as resistant 30 years ago, although in recent years resistant areas are beginning to appear that are remote from the original area.

Increased resistance in the black scale has been shown to occur in the motile young (Gray & Kirkpatrick 1929b) and in the later stages (Gray & Kirkpatrick

1929; Lindgren & Dickson 1943). The eggs of this species, however, do not show a difference in resistance between the two strains (Swain & Buckner 1940; Lindgren & Dickson 1943). Parthenogenetic reproduction occurs in the black scale as contrasted with sexual reproduction in the red scale, and the number of generations in the latter insect is two or three times greater.

The citricola scale occurred in the citrus groves of southern California a few years before it was definitely identified in 1909. HCN fumigation had been practiced for many years for other scale insects in at least some of the groves where the citricola scale was first observed. By 1914 this species occurred in such numbers in parts of Riverside, San Bernardino, Los Angeles and Tulare counties that fumigation was directed against it. Resistance to HCN was first established in a particular grove near Riverside in 1926 (Quayle 1938). The area where resistance occurred increased very rapidly and in the course of 3 or 4 years included most of the area infested by this species in southern California. Within this area there are considerable stretches of barren land and it is scarcely possible that the strain could have covered the area in such a short time from a single focus. This fact, together with the complete change within the short period from satisfactory to very unsatisfactory commercial fumigation results, suggests that more than a single mutant must have appeared.

The history of the citricola scale in Tulare County is somewhat different from its history south of the Tehachapi mountain range. In the course of a few years it increased from an unknown pest to a very abundant one and over a large part of the citrus area of the county. Fumigation, starting in 1914, was the standard of control for a number of years. Later sulfur treatment, which was necessary for the citrus thrips, took care in large measure of the control of the scale, and consequently fumigation greatly declined. There appeared to be less marked evidence of resistance to HCN in that area and fumigation is still practiced to a limited extent.

Earlier in this paper it was mentioned that in the case of some of the insects discussed direct experimental evidence was not available in a particular locality as to conditions of resistance until the fact was actually established. In the case of the citricola scale, however, direct experimental comparisons were made of scales from localities where they were resistant or nonresistant, respectively, and 3 or 4 years later the insects from the localities in which they had not been resistant were definitely shown to have increased in resistance. Somewhat similar comparisons are also available for the red scale, and the citrus thrips which will be discussed later.

Some apparent inconsistencies may be detected in the discussions of the black and citricola scales. It was stated that the main area where the black scale is resistant remains compact, while that of the citricola scale is more extensive and the spread occurred more rapidly. Both insects have, in the areas in question, about the same life cycle and are similar in habits. Resistance was also observed within a shorter period in the use of the insecticide in the case of the citricola scale. It was also stated that the citricola scale spread rapidly in Tulare County after it became established there, and this fact may not be inconsistent with the rapid spread of the resistant strain from a single focus in southern California instead of probably from several foci as surmised.

The discussion thus far has pertained to four species of insects that belong to the same group (scale insects), one of which showed a difference in resistance to a contact spray and the other three to a fumigant. The significant work of Hough (1928, 1929, 1934) on the codling moth has shown the same phenomenon to occur in an entirely different type of insect and to different types of insecticides but also including HCN. The first extensive studies on the genetics of the strains were also presented. The work on the relative resistance of the codling moth, *Carpocapsa pomonella* (Linn.), was carried on with strains from widely separated localities, Colorado, Washington and Virginia.

The codling moth first appeared in the Grand Valley of Colorado, from whence came the Colorado strain, about 1891 (Hough 1934), and general spraying with arsenate of lead began 3 or 4 years later. Difference in resistance between the strains from Colorado and Virginia was shown in 1928 (Hough 1928). Apple spraying in the Winchester district in Virginia, from when came the Virginia strain of

codling moth, began about 1900. When spraying first started in both these districts, one (calyx) spray only was practiced. The number of sprays had increased to two in Colorado by 1900, and in Virginia by 1916. By 1930, the number had increased to four in Virginia and to eight, ten and twelve in Grand Valley, Colorado. Codling moth studies also included a strain from the Yakima apple district of the state of Washington (Hough 1929). The Washington strain was intermediate between the Colorado and Virginia strains but nearer the Virginia strain in its resistance to arsenate of lead. At the same time the number of sprays recommended in the field in Washington was intermediate between that of Colorado and Virginia, thus bringing out the same relationship in regard to relative resistance as that shown by careful laboratory experiments.

Differences in relative resistance in the strains of the young larvae of the codling moth have been shown to occur with such non-arsenical sprays as cryolite, barium fluosilicate, rotenone, cuprous cyanide and nicotine; and to the fumigant HCN, and later stages of the egg to the same fumigant. The fact that the Colorado strain exhibited greater resistance to such a range of insecticides as well as to starvation and to its greater ability to enter unsprayed as well as sprayed apples, leads Hough to conclude that a strain of greater vigor in general is represented.

Haseman and Meffert (1933) by microtechnical methods injected lethal dosages of arsenate of lead in the alimentary canal of fully mature codling moth larvae. Also lethal dosages of sodium arsenite into the haemocoele and the alimentary canal. The conclusion of these authors was that the Colorado, Missouri and Virginia codling moth larvae were all equally tolerant to arsenic. This does not disprove the findings of Hough, whose experiments dealt with the natural procedure of the newly hatched codling moth larvae in entering the apple. Resistance or increased resistance as previously defined, is considered as synonymous with the decreased effectiveness of the normal use of the insecticide.

It is well known that individual differences in resistance to an insecticide may be great in any insect population. In the case of the confused flour beetle, *Tribolium confusum* Duv., Gough (1939) has found this to be true for HCN and also that the greater resistance may be inherited through several generations. The writer found (unpublished data) that the convergent ladybird beetle *Hippodamia convergens* Guér. surviving one HCN fumigation will survive a second fumigation in greater numbers than will the original population a single fumigation.

McGovran *et al.* (1939) have shown that houseflies that have been knocked down (paralyzed) with ether, acetone, or kerosene sprays low in pyrethrum content are more resistant to kerosene sprays high in pyrethrum content than were normal active flies. Gray & Kirkpatrick (1929a) showed that the black and red scales, when subjected to a sublethal or stupefying dose of HCN, were more resistant to the lethal dose that immediately followed than scales not so stupefied. (See also Lindgren 1941 and Lindgren & Dickson, 1943.)

Work with the larvae of the screw worm (Knipling 1942) has added additional important data to the question of relative resistance in insects to insecticides. The data are important because they are concerned with an insect of a different order than any of those thus far discussed and one which feeds in a different manner, that is, on the medium in which it is submerged. The experimental procedure is much simplified with such an insect once a suitable medium for rearing is found. In addition to finding that a greater resistance was acquired to phenothiazine, Knipling showed that the F_1 and subsequent generations from crosses inherited an intermediate degree of resistance. Unlike the young codling moth larvae, however, resistance in the screwworm larvae was specific for phenothiazine only; at least a difference in resistance was not shown for two other insecticides tested.

The last of the group of insects for which experimental evidence of increased resistance has been shown is represented by the citrus thrips (Boyce *et al.* 1942, Persing *et al.* 1942). While the evidence is not as yet extensive it is rather striking, and the phenomenon has appeared in this species very shortly after the insecticide was first used. The citrus thrips has been a pest of citrus trees in the southwestern United States for the last 30 years, but the insecticide tartar emetic-sucrose bait

spray to which resistance developed, has been in use but 3 or 4 years. It was first used commercially in 1939 and 1940, and complaints of unsatisfactory results appeared in a particular area in 1941. In 1942, experimental results confirmed the fact of resistance in an area of about 300 acres in the San Fernando Valley and in one or two smaller areas in Kern and Tulare counties in California. Here again the circumstances support the fact that more than one mutant must have arisen at practically the same time, because it is scarcely conceivable that spread would have occurred from a single mutant in a single season over the space of 100 miles or more from San Fernando Valley to Edison, in Kern County or Porterville, in Tulare County. Most of this space consists of uncultivated land and besides there is a mountain range of considerable height. Spread by man in his transportation operations might, of course, be more likely.

DISCUSSION.—Some insects in which investigational evidence seems to support increased resistance to insecticides have been mentioned. In most of these cases commercial field experience with insecticides, given sufficient time, would have furnished rather convincing circumstantial evidence in support of the same claim. As a matter of fact, in practically all cases it was the field experience that first suggested such a possibility, which was later amply confirmed by the laboratory data.

It is to be noted that the time required for increased resistance to become manifest, or be first detected, varied greatly in the different species, that is, from a year or two to 25 years. In fact, after resistance to one insecticide had increased the same increase in resistance to other insecticides was evident at once in two cases, namely, in codling moth larva to sprays other than arsenate of lead and in red scale to fumigants other than HCN.

As to the probable genetic basis of resistance, it is assumed that the mutant gene or genes involved were already present in the population or possibly originated during the course of the treatment. The insecticide serves to select out the individuals carrying the gene or genes which may be specific for a single insecticide, or for several, or for factors other than insecticides, as pointed out by Hough in the hardier strain of the codling moth. The frequency of the mutant gene in the population will depend upon the species and the number of generations of the insect per unit of time, and on the duration and efficiency or selective power of the treatment. Differences in these factors may account for some apparent inconsistencies with the insects under discussion. The citrus thrips has the greatest number of generations (8–10 annually) and resistance appeared soonest after the use of the insecticide. The red scale, however, has two or three times the number of generations of the black scale, yet resistance was first observed at about the same time in both species after the insecticide was first used.

With the background outlined we may be justified in assuming that there are other cases of increased resistance for which experimental evidence is lacking. While such evidence is convincing, for the codling moth as between two or three different sections, there are many other sections where codling moth control is practiced where the number of spray applications has increased. In spite of the increased number of sprays and the increased thoroughness with which modern spray equipment applies them, the percentage of wormy apples has not diminished but rather increased in many cases.

The walnut strain of the codling moth was satisfactorily controlled when spraying was first practiced around 1920 with one application of basic arsenate of lead. It is not now satisfactorily controlled with a better application by means of high towers and superior equipment. It should be noted of course that in the early period of codling moth infestation in walnuts in southern California (the first record was in 1913) up to the middle 20's the percentage of infested nuts was not so high as in later years, although within that former period a 40 per cent infestation is recorded. The walnut grower is under a handicap because the less toxic basic arsenate of lead rather than acid arsenate of lead must be used on account of tree injury. But in practically all apple spraying the acid lead is used and the same increased resistance or difficulty of control has occurred.

The citrus red mite, *Paratetranychus citri*, in southern California was satisfactorily controlled for many years, or from 1903 to about 1920, by sulfur, applied

either dry or in the form of the lime-sulfur spray. Sulfur for citrus red mite was replaced by petroleum oil sprays in the early 20's. Where sulfur has been applied in recent years the results generally have been unsatisfactory. Persons who have passed through this history and are qualified to pass judgment are very certain about the status of sulfur as thus expressed. It is true that with the advent of the highly refined oil sprays, particularly the heavier grades that were first used, the citrus red mite was more effectively controlled than it ever was with sulfur. This was due largely, to the much more prolonged effectiveness of the oil residue. And with the later appearance of *Selocide* (potassium-ammonium-seleno-sulphide) and *DN dust* (dinitro-ortho-cyclohexylphenol), when comparisons were made with sulfur, the sulfur treatments were generally unsatisfactory.

Another case of what may appear to be an increased tolerance to an insecticide is the common red spider, *Tetranychus telarius*, in greenhouses to *Selocide*. This material, according to reports, was outstanding as a method of control generally in the greenhouses of the Eastern States but after a comparatively few years was not satisfactory and is scarcely used any longer for such control. Cryolite for the control of the walnut husk fly, *Rhagoletis completa*, a rather recent pest of Persian walnuts in southern California, was formerly satisfactory (Boyce 1934) but in recent years the results have been much less so. Recent reports from the agricultural commissioner's office of San Diego County complain of the unsatisfactory results with tartar emetic-sucrose spray for the control of the gladiolus thrips, *Taeniothrips simplex*.

However, there is nothing very convincing about making comparisons as to the effectiveness of an insecticide during a certain period of years with a certain other period of years in the absence of experimental evidence. The standard of effectiveness is bound to be higher now than formerly. Additional insecticides have become available for more exacting comparisons. In some cases, in addition to the gross type of injury of an insect, other more subtle types of injury, which are important, are later recognized. The increase in area of contiguous plantings of the host crop favors the increase of the insect. The insect becomes adapted to different conditions, as to both climate and hosts. Concrete examples of all of these conditions mah be cited within such a limited area as southern California. Such factors tend to make the problem of satisfactory control more difficult now than in the past. But if changes in the insect as to food and climate are recognized, is it going too far to assume that the insect may also change in its reaction to an insecticide?

SUMMARY.—There have been reviewed seven species of insects for which experimental evidence has been previously published supporting the proposition that these insects have increased their normal resistance to insecticides. These species represent four different orders of insects of widely different food habits which have shown an increase in resistance to insecticides representing contact and stomach poison sprays, fumigants, a bait spray, and where the insecticide is incorporated in the medium in which the insect lives. Examples of a few other insects and mites are mentioned where circumstantial evidence tends to support the same proposition. This is a disconcerting note in regard to the permanence of insect control methods as has already been amply demonstrated in some of the cases discussed, but it is a challenge to entomologists.—2-10-43.

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TOMATO PINWORM QUARANTINES

The Idaho quarantine pertaining to the tomato pinworm was repealed effective May 22, 1943. This is the fourth state to remove the quarantine since the Western Plant Board, at its meeting in June 1942, recommended lifting of the quarantines, inasmuch as the pinworm did not seem to be of economic importance in the Pacific Northwest. The State of Utah apparently continues to maintain its quarantine concerning the pinworm.

Precautions Necessary in Estimating Populations of Small Animals[1]

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The task of estimating populations of small animals is not always easy because of complexities in nature and numerous difficulties human beings have in understanding these complexities. Gathering data, free of bias and representative of the true parent from which the samples are taken, is extremely difficult and often requires a great deal of forethought, much ingenuity and no little amount of careful inspection of results. The object of this article is to point out some necessary precautions in estimating the populations of small animals. The estimates are made on the number of European red mites because some spraying experiments happened to be underway for that pest, but the precautions found necessary in making the counts are probably similar and will apply to many other species. The immediate object of making the counts was to determine the effect of the spray.

APPARATUS.—During the summer of 1941 counts were made of the number of European red mites, *Paratetranychus pilosus* C. & F., per leaf area of Delicious apple tree leaves by two men who used a folded cardboard apparatus for making the counts. The cardboard, AB–CD–EF, was folded in the middle on line CD and had a square cut out of each half so that when a leaf was inserted and the pieces of the card were pressed together counts could be made on one square inch of the upper surface and by turning the card over, counts could be made on one square inch of the lower surface. Leaves were inserted into the apparatus at random; that is a leaf was placed into the folded card without making the hole in the card fall on the center of the leaf. Sometimes the hole or cut-out portion of the apparatus fell near the apex, sometimes near the petiole and sometimes near the center. By inserting the leaves at random a better estimate of the number of mites per square inch of leaf area can be obtained. Using such a device saves counting all the mites upon a leaf and enables counts to be made on the upper and lower surfaces quickly, and eliminates variation in leaf area.

Reading lenses were used to detect the mites. Several low power microscopes were used for a few counts in order to determine the best type of lens to use. It was difficult to keep locations on the leaves while the microscope was moved from place to place and focused. The animals moved too rapidly to keep up with them while the eye was held on the eyepiece. It was soon discovered reading lenses were superior to any available microscope as far as accuracy and speed were concerned. A reading lens can be placed on an object on the leaf which resembles a mite; if it is a mite, it usually moves and of course is enumerated. This can be done quickly for the counter has the apparatus in one hand and the lens in the other. With the reading lens one can see the entire square inch of leaf area and can follow the movements of the animals, thus eliminating duplicates in the counts. The reading lens can be used for several hours without causing much eye strain.

It was noticed that the mites ran under the part of the apparatus which was not exposed to the light and that they ran out into the light from the shaded parts. Observations were made as to whether more ran from the part exposed to the light than from the shaded parts. These records showed that on the average there were as many animals going from the light as into the light while the enumerations were being made. This would indicate that the apparatus used did not inject bias into the results.

TRAINING ENUMERATORS.—It seems important to train the people, making the counts, how to detect mites, eggs, and foreign particles on the leaves because at certain stages the animals are small, inactive, and resemble grains of dust. It requires several hours of counting before the counters have confidence in their enumerations.

Some of the avoidable errors detected in the preliminary training were those resulting from clustering of young mites;

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mites hiding in inequalities of the leaves; the greater activity of mites on sunshiny days; and the fact that leaves from one side of the tree gave significantly higher counts apparently because that side of the tree was in better vigor. One small error not eliminated was the difference between reading lenses.

Inasmuch as significantly similar results from sample counts were not secured until after these various sources of error

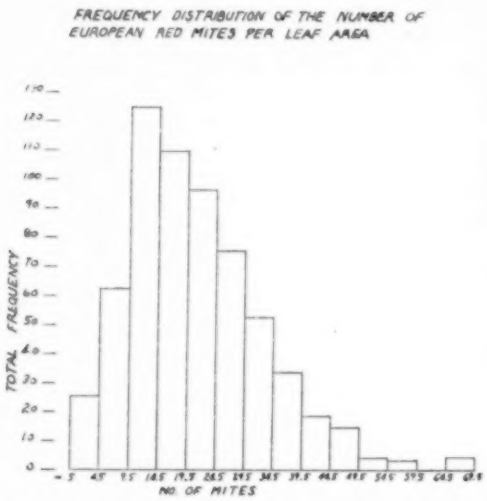

FIG. 1.—Distribution of mites in initial infestation.

were eliminated, the result of counts made during the first eight hours were discarded. By the end of the training period the men making the counts realized the necessity for picking leaves at random from the tips of twigs, near the trunk, and from the central regions of the branches near the top, middle, and lower parts of the tree which had an estimated 200,000 leaves.

RESULTS OF THE COUNTS.—The following figures indicate how the averages from the counts varied, for different dates:

July 10	July 12	July 15 and 16	July 17–19
14.30	18.70	21.20	20.64

These values show that the number of mites per leaf area increased during the season indicating that eggs hatched all over the tree. There is a significant difference between the averages of the counts made on July 10 and July 12, and also a significant difference between the averages for July 12 and July 17–19. There is no significant difference between the averages for the last two counting periods. The last statement suggests that the average number of mites per 2 square inches of leaf area from July 15 to July 19 was about 20.91 mites, this value being the average of the counts made during the last two counting periods. During this period the number of animals per leaf area remained nearly constant. Since the counts were about the same for the last five days, it seemed plausible to say that the value, 20.91 mites, was representative of the population of the mites for this apple tree per 2 inches of leaf area for this time in the season. The frequencies for these counts are exhibited in figure 1, grouping being used since the range was so large. The standard deviation, 11.86 mites, shows that the scatter about the mean was large. This means that there was a great deal of variability in the individual counts and also indicates difficulties in securing a representative sample. There were 70.4 per cent of the counts within one standard deviation of the mean, showing that the mean is a good representative of the number of mites per leaf area.

After the averages of the counts from day to day ceased to fluctuate significantly, samples were taken immediately for determining the size of a sample to be approximately equal to the mean of the counts from July 15 to 19. Samples of 100, 150 and 200 leaves were taken at random from the tree. The averages of the samples containing less than two hundred leaves were significantly different from the mean 20.91 mites, which was assumed to be the population of the tree per 2 square inches area for this time. The average of the samples having 200 or more leaves did not differ significantly from the average accepted for the tree. Since it is difficult to take a random sample from a large apple tree, it would be better to use 300 leaves taken from all over the tree than two hundred.

Areas of 100 entire leaves were found by using a planimeter. The average of these planimeter measurements was 3.11 square inches for each upper and lower surface. This means that if the average number of mites per square inch is 10.46 and that if there are 200,000 leaves on the tree that there are roughly about 13,012,240 mites on the tree.

POPULATION ON UPPER AND LOWER

LEAF SURFACE.—It is rather interesting to compare the enumerations on the upper and lower surfaces of the leaves. These averages for the last 618 leaves, before spraying are respectively 8.06 mites and 12.86 mites. Since these values are significantly different, it suggests that these animals prefer the lower surface and that in making counts per leaf area this should be taken into consideration.

The 50 counts shown in table 1, taken at random from the records, reveal the above apparent fact with reference to the upper and lower surfaces of the leaves.

Some of the samples showed that 90 per cent of the leaves counted had more mites on the lower than on the upper surface. Every sample on every day showed that a large majority of the leaves contained more mites on the lower surface than on the upper. The distributions of the counts for the upper and lower surfaces are exhibited in figure 2. The heavy line in each histogram was erected at the average. The one erected at the average number of mites on the lower surfaces is considerably to the right of the other. The distribution of the counts on the lower surface extends to the right much further than the other, showing that there were many more leaves with larger numbers of mites on the lower surface than on the upper. Eighty-two per cent of the items in the distributions of the counts on the upper surface were below the mean of the distribution of the counts on the under surface. Since there are more mites on the lower surface of the leaves, this should be taken into consideration when making a census.

Table 1.—Number of European red mites per square inch of leaf surface.

Upper	Lower	Upper	Lower	Upper	Lower
4	13	22	10	10	18
9	29	4	11	5	11
12	4	14	7	11	15
3	9	28	7	3	25
13	12	3	1	1	25
5	7	23	7	6	16
5	17	10	5	4	23
21	47	7	4	6	6
7	11	9	13	31	15
14	22	12	12	12	4
2	4	7	13	4	18
16	14	11	14	17	9
19	28	5	10	14	8
1	3	6	19	1	12
7	23	5	12	3	3
9	10	4	19	2	16
14	12	13	12		

RESULTS AFTER SPRAYING.—Three days after spraying with rotenone (1.0 per cent rotenone in mannitan monolaurate, 1 pint in 100 gallons), counts were initiated to determine whether or not the spray used was effective in killing the mites, samples being taken each week thereafter. The averages together with the dates and per cent of kill reveal the results. (table 2).

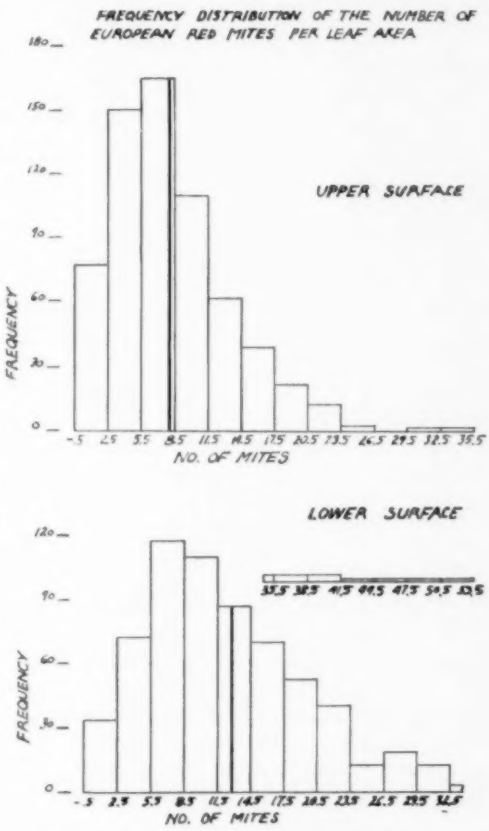

FIG. 2.—Comparative distribution of mites on upper and lower surfaces.

Table 2.—Average number of mites per 2 square inches of leaf areas.

	July	Aug.	Aug.	Aug.	Aug.	Aug.	Sept.
Date	29	2	9	16	23	30	19
Ave.	2.46	2.09	0.67	1.38	0.80	0.77	2.26
Per cent kill	88	90	97	93	94	94	89

These average values are significantly less than each of the averages of the samples taken before the spray was applied, showing that the spray was effective in killing a large majority of the

mites. The per cent of kill figures were found by dividing the differences of the respective averages before and after spraying by the average population (20.91) mites before spraying; for example the per cent 88 in the above table was found by dividing the difference (20.91 −2.46) by 20.91. These per cents indicate that the spray was effective but that it did not eradicate these animals. Since the area of one side of a leaf on the average is 3.11 square inches, there were left on the average about 3 mites per leaf. On examining these averages it is seen that the per cent of kill did not reach its greatest value until August 9. On September 19 the number of mites had increased showing that eggs were again hatching.

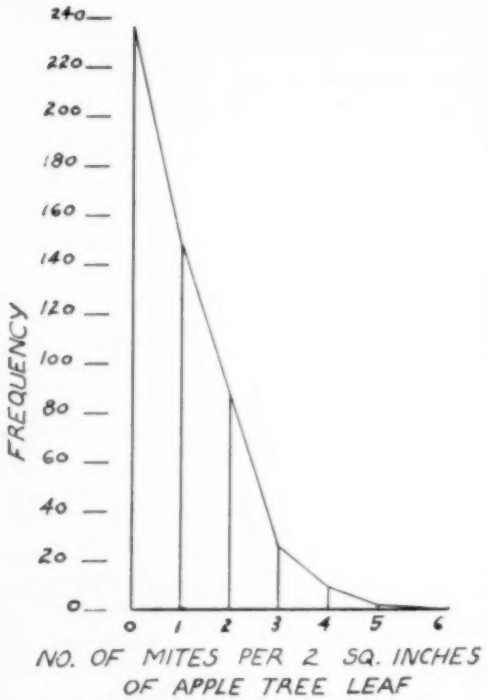

FIG. 3.—Distribution of mites after spraying.

It is very important to spray immediately after a good estimate of the mite population of the tree has been determined by an adequate random sample and to make counts again after the spraying as soon as possible.

The distribution of the enumerations made after spraying is exhibited in figure 3. Most of these values are less than two; but *several* leaves were found with more than *10 mites* per leaf area. The averages pertaining to the upper and lower surfaces were about the same after spraying, showing that the material used was strong enough to reduce the mite population to between .34 to 1.19 animals per square inch of area.

SUMMARY.—This article has shown that it is important in estimating European red mite population per unit leaf area of Delicious apple leaves to consider the following:

Selection of adequate apparatus for enumerating these tiny animals per leaf area.

Methods for making random samples with the apparatus.

Sufficient training of the enumerators before using results.

Investigation of vigor of the various parts of the tree.

Critical examinations of the results as the counts are made for detecting bias in the samples.

Comparison of results from the upper and lower surfaces of the leaves.

Determination of what is an estimate of the population of mites.

The proper time for making counts after spraying.

Tests for comparing results.—4-12-43.

CONTRIBUTIONS FROM AUSTRALIA

Contributions Nos. 163 and 165 from the Council for Scientific and Industrial Research of Australia have just been received from Canberra. The first deals with the control of the tuber moth in stored potatoes by the use of magnesite applied as a dust (200 mesh). Considerable success is reported. The second publication describes the control of *Pediculoides ventricosus* in insect cultures by the use of an oil solution of dinitro-ortho-cyclohexylphenol. The material is applied as a barrier on the sides and lids of the culture jars merely by wiping them with a cloth saturated with the solution.

Some Effects of Alternating Temperatures and Exposure to Cold on Embryonic Development of the Beet Leafhopper[1,2]

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Many studies on insect development have shown more rapid development under alternating or varying temperatures than would be expected on the basis of the relative effects of constant temperatures (Cook 1927; Peairs 1927; Shelford 1927; Ludwig 1928; Parker 1930). Since results obtained in more general studies of development of the beet leafhopper with relation to temperature indicated that the percentage of acceleration varied with the temperatures involved and also with the time of exposure at different temperatures,[3] the work was extended in the present study of the egg stage in an attempt to delineate these relationships more clearly.

Methods.—The eggs used in these experiments were obtained from overwintering females taken from outdoor hibernation cages during the winter. Small sugar beets grown in the greenhouse in 4-inch pots were used as host plants. Groups of eggs used in the different experiments were obtained by placing the females on the plants in small cages designed to fit snugly around the petiole. After a 12-hour period these cages were removed and the exposed portion of the plant containing the imbedded eggs was marked with ink. Toward the end of embryonic development cages were replaced over the same sections of the petioles to confine the young nymphs.

Exposure at different temperatures was effected by transferring the plants containing the imbedded eggs from one controlled chamber to another (Annand & Harries). The temperature of the cabinets was controlled within approximately $\pm 0.5°$ F., and relative humidity was controlled at approximately 50 ± 1 per cent at all temperatures. Continuous records were obtained with hygrothermograph recorders, and temperature and humidity within the cages were checked with a thermometer and small dewpoint tube. The amount of temperature lag following transfers from one temperature to another was checked by means of small thermocouples inserted in the plant tissue.

The eggs were deposited during a 12-hour period, 9 A.M. to 9 P.M. or vice versa, under the conditions of each experiment and hatching was recorded at 9 A.M. and 9 P.M. The theoretical time necessary for development in alternate exposures to two different temperatures was computed as follows: Since 6.27 days were required for completion of the stage at 90° F., 4 hours represented 2.66 per cent of the time. The remaining daily period of 20 hours was 9.03 per cent of the total time of 9.23 days required for the entire stage at 80° F. Accordingly, for 1 day under these conditions, 11.69 per cent of the total time would be completed and the duration of the stage should be 8.56 days. In studies of the effect of exposure to cold for various periods, the eggs were deposited at 90° F. and the developmental time was calculated in the same way as that for eggs held continuously at this temperature which were used for comparison.

Results and Discussion.—The approximate duration of the egg stage was determined for exposures of 4, 8, 12, 16, or 20 hours at 90° F. alternating with exposure for the remainder of a 24-hour period at one of the following temperatures: 80°, 70°, 60°, 50°, or 40° F. The results of these tests, given in table 1, show that development was always completed in less time than would be expected on the basis of that required at constant temperatures. These results, in terms of the percentage acceleration in rate of development, are arranged in table 2 to illustrate differences in relative effects of the various periods of exposure to different temperatures. In most cases the data show a progressive increase in acceleration in rate of development with successively shorter daily exposures at the higher temperature. With the exception of the series alternately exposed to 90° and 40° F., the percentage of acceleration increased with greater differences in temperature. Inasmuch as the daily period of higher temperatures tends to shorten with increase in the daily range

[1] *Eutettix tenellus* (Bak.); order Homoptera, family Cicadellidae.

[2] This study was conducted at Twin Falls, Idaho, under the general direction of J. R. Douglass and W. C. Cook, to whom the writer is indebted for many helpful suggestions.

[3] Harries, F. H., and J. R. Douglass, Bionomic studies of the beet leafhopper with special reference to effects of meteorological factors. Unpublished manuscript.

Table 1.—Embryonic development in alternate exposure to different temperatures for different periods each day as observed and as calculated on basis of results obtained at constant temperatures.

Daily Exposure Periods				Time for Embryonic Development		
At 90° F.	At lower temperature	Lower Temperature	Eggs	Observed	Calculated	Difference between observed and Calculated[1]
Hours	*Hours*	*°F.*	*Number*	*Days*	*Days*	*Per Cent*
		80	511	9.23±0.03	—	—
0	24	70	270	17.40±0.06	—	—
		60	32	43.84±0.30	—	—
		80	792	8.10±0.02	8.56	−5.4
		70	509	12.61±0.02	13.42	−6.0
4	20	60	225	19.98±0.04	21.94	−8.9
		50	209	29.65±0.05	37.62	−21.2
		40	150	35.45±0.09	37.62	−5.8
		80	683	7.59±0.01	7.98	−4.9
		70	511	10.69±0.02	10.93	−2.2
8	16	50	52	13.42±0.07	14.63	−8.3
		50	150	16.15±0.05	18.81	−14.1
		40	508	17.83±0.03	18.81	−5.2
		80	501	7.15±0.02	7.47	−4.3
		70	427	8.74±0.02	9.22	−5.2
12	12	60	267	10.12±0.03	10.97	−7.7
		50	754	11.66±0.01	12.54	−7.0
		40	441	11.95±0.02	12.54	−4.7
		80	235	6.85±0.03	7.02	−2.4
		70	512	7.65±0.02	7.97	−4.0
16	8	60	380	8.25±0.03	8.78	−6.0
		50	641	8.82±0.02	9.40	−6.2
		40	771	8.90± 0.02	9.40	−5.3
		80	227	6.60±0.01	6.62	−0.3
		70	269	6.82±0.03	7.02	−2.8
20	4	60	300	7.01±0.02	7.31	−41.
		50	341	7.17±0.02	7.52	−4.7
		40	1214	7.20±0.01	7.52	−4.3
24	0	—	603	6.27±0.02	—	—

[1] (Observed-calculated) 100/calculated.

Table 2.—Differences in observed and calculated durations of the egg stage, expressed as percentage acceleration in rate of development and arranged to illustrate effects of various periods of exposure at different temperatures.

Daily Exposure to Lower Temperature	Acceleration Following Alternate Exposure at 90° F. and Indicated Lower Temperature					
	80° F.	70° F.	60° F.	50° F.	40° F.	Mean
Hours	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
20	5.7	6.4	9.8	26.9	6.1	11.0
16	5.1	2.2	9.0	16.5	5.5	7.7
12	4.5	5.5	8.4	7.5	4.9	6.2
8	2.5	4.2	6.4	6.6	5.6	5.1
4	0.3	2.9	4.3	4.9	4.4	3.4
Mean	3.6	4.2	7.6	12.5	5.3	

of temperature occurring in the spring and fall, both factors of temperature and time of exposure would apparently act to the advantage of the species in permitting more development than would otherwise occur during the cooler seasons of the year.

The general relations shown by the data are illustrated in figure 1 by a three-dimensional graph, in which differences in temperature and time of exposure at different temperatures are represented on the horizontal axes and percentage acceleration in rate of development is shown on the vertical axis. This isometric graph differs chiefly from the solid model shown by Cook (1927) in studies of the effect of constant and alternating temperatures on growth and metabolism of cutworm larvae, in that the relations are based on combinations of different lower temperatures with a common maximum instead of higher temperatures with a common minimum. The results are in general agreement with those of Cook, who found that the amount of acceleration increased with greater differences in temperature within a range of 8° to 32° C. and with shorter daily exposures of 8 and 4 hours at the higher temperature. Cook also found that the rate of metabolism at higher temperatures was greatly accelerated in the first few hours following exposure to cold near developmental zero and then declined to a constant value. This effect was renewed in successive exposures to cold to maintain an accelerated rate at the higher temperature.

The reversal of trend shown by results of the 90°–40° F. alternations suggests the possibility that some development may have occurred at 50° F. or that some physical factor was present that was not controlled in the experiments. Since 50° F. is only slightly below developmental zero and 40° F. considerably below this level, any lag in heating and cooling in the 90°–50° F. transfers would occur largely within the effective temperature range and would apparently be rather closely compensating, while in the 90°–40° F. alternations most of the lag in cooling would occur below the minimum for development and would therefore fail to balance a lag in heating at the higher temperature.

Studies of the thermal lag following transfers from one temperature to another showed that most of the temperature change occurred very quickly and perceptibly lagged only a few degrees over a period of 5 or 6 minutes. Except where time differences in the 90°–50° and 90°–40° F. series are very small, as in the 16- and 20-hour exposures at 90° F., a lag of the full temperature difference for 5 minutes daily following transfers from 40° to 90° F. would account for less than 0.1 day in cases where differences of 0.29, 1.68, and 5.80 days (as in the 12-, 8-, and 4-hour exposures at 90° F., table 1) are shown by the results. During alternate exposures to 90° and 50° F. the total time spent at the lower temperature ranged from about 5 to nearly 6 days. When eggs deposited during a 12-hour period at 90° F. were transferred to 50° F. for an interval of 6

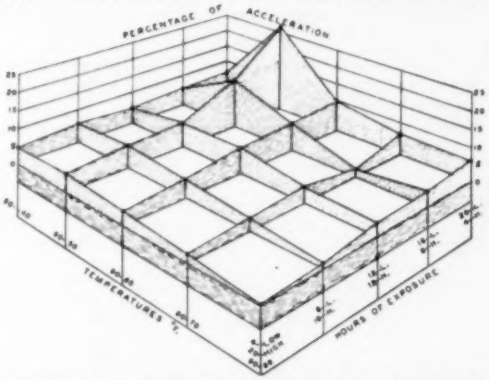

FIG. 1.—Graph illustrating the effect of different times of exposure at different temperatures on the percentage of apparent acceleration in rate of development.

days and then returned to the higher temperature, the total developmental time at 90° F. decreased to 6.09 ± 0.02 days in comparison with 6.27 ± 0.02 days for eggs held continuously at this temperature. If this acceleration is attributed to development at 50° F. rather than to a stimulus resulting from exposure to cold, a difference of about 0.2 day in developmental time between the 90°–50° and 90°–40° F. alternations would also fail to account for the major difference of 1.68 and 5.80 days (exposures to 90° of 8 and 4 hours, table 1) in results of the two series. In view of these considerations it would seem that the accelerative effect was actually greater in exposures to 50° than at 40° F. and that the relative amount of acceleration increased with greater differences in temperature only within the range of 90° to 50° F.

In studies of development of the Japanese beetle (*Popillia japonica* Newm.) under constant and alternating temperatures, Ludwig (1928) found that the percentage of acceleration varied with the temperatures involved. According to Ludwig's well-known generalization, an ac-

celeration was produced when temperatures occurring between the optimum and minimum for development were imposed alternately with lower temperatures, and a retardation was produced when temperatures occurring between the minimum and optimum were alternated with temperatures above the optimum. No significant differences were observed when both temperatures were between the minimum and optimum for development. Similar results were also obtained by Ludwig and Cable (1933) in studies of pupal development of *Drosophila melanogaster* Meig.

Table 3.—Time required for development of beet leafhopper eggs at 90° F. after exposure for various intervals at 50° and 40° F.

Days Exposed to Temperatures Below that Required for Development	Time Required for Development at 90° F.	Difference Due to Exposure to Cold	
	Days	*Days*	*Per Cent*
0[1]	6.27±0.02	0	0
50° F.			
2	6.36±0.02	0.09±0.03	1.4
3	6.36±0.04	0.09±0.04	1.4
4	6.27±0.04	0.00±0.04	0.0
5	6.21±0.02	−0.06±0.03	−1.0
6	6.09±0.02	−0.18±0.03	−2.9
8	6.06±0.03	−0.21±0.04	−3.3
9	5.93±0.02	−0.34±0.03	−5.4
15	5.92±0.02	−0.35±0.03	−5.6
40° F.			
2	6.29±0.03	0.02±0.03	0.3
3	6.17±0.02	−0.10±0.03	−1.6
4	6.33±0.04	0.06±0.04	1.0
5	6.58±0.02	0.31±0.03	4.9
6	6.54±0.04	0.27±0.04	4.3
8	6.43±0.02	0.16±0.03	2.6
9	6.53±0.05	0.26±0.05	4.1
15	6.61±0.08	0.34±0.08	5.4

[1] Not exposed to temperatures below that required for development.

Since the highest temperature employed in the present experiments (90° F.) is near the optimum, conditions involving higher temperatures comparable to those used in Ludwig's studies of the Japanese beetle are not represented. The accelerative effect of exposure to temperatures below the minimum for development in the example of the 90°–40° F. alternations is in accordance with Ludwig's generalization, but since alternations of temperatures between the optimum and minimum also produced some acceleration the data fail to accord with Ludwig's results in this respect.

EXPOSURE TO COLD.—The beet leafhopper passes the winter in the adult stage, and the eggs are not ordinarily subjected to extreme or extended low temperatures. Egg laying begins early in the spring, and embryonic development is often suspended or greatly reduced by cold periods occurring in March and April. The effect of such exposures and their relation to the influence of similar minima in daily temperature fluctuations was studied by holding eggs in early stages of development at 40° and 50° F. for various periods and then permitting them to develop at a favorable temperature of 90° F.

The results, which are summarized in table 3, show only slight or random deviations with shorter periods at the lower temperatures, but differences that are usually more than three times the standard errors with longer exposures. These differences show a significant reduction in the developmental time at the higher temperature following exposure to 50° F. and a definite retardation after exposure at 40° F. Shortening of the developmental time following exposure at 50° F. suggests that some development may occur at this temperature. If such is the case, the amount of acceleration shown for the 90°–50° F. alternations will be slightly reduced. The data for exposure to 40° F. show that more prolonged exposure to cold may retard subsequent development at a favorable temperature, in contrast to an opposite or accelerative influence produced by brief alternations of the same higher and lower temperatures.

Similar relations for embryonic development of the Japanese beetle were described by Ludwig (1928, 1930), who found an accelerative effect when eggs were alternated between low and higher temperatures during the course of development and a definite retardation in rate of development at a higher temperature following exposure of 1 to 4 weeks at temperatures below developmental zero. This contrasts with the marked accelerative influence of extended exposure to cold on grasshopper eggs shown by Bodine (1927) and Parker (1930), but it seems to be fairly common, since embryonic development of *Ephestia kuehniella* Zell. (Hase, 1927), *Cimex rotundatus* Sign. and *C. Lectularius* L. (Hase, 1930), and *Prodenia litura* F. (Janisch, 1930) is apparently retarded at favorable temperatures following exposure to low temperatures.

SUMMARY.—In studies of the beet leafhopper (*Eutettix tenellus* (Bak.)) under

controlled conditions in the laboratory, embryonic development was always completed in less time under alternating temperatures than would be expected on the basis of that required at constant temperatures. In exposures of 4, 8, 12, 16, and 20 hours daily at 90° F. alternating with exposures for the remainder of each 24-hour period at 80°, 70°, 60°, or 50° F., the percentage of acceleration increased with shorter exposures at the higher temperature and with greater difference between the higher and lower temperatures. Inasmuch as the daily period of higher temperatures tends to shorten with increase in the daily range of temperature occurring in the spring and fall, both factors of temperature and time of exposure would apparently act to the advantage of the species in permitting more development than would otherwise occur in the cooler seasons of the year. Some acceleration was also produced in similar periods of alternate exposure to 90° and 40° F. but continuous exposures of 5 to 15 days at 40° F. retarded subsequent development at the higher temperature.

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C. V. RILEY CENTENNIAL

Readers of the Journal may be interested in the letter reproduced below concerning the commemoration of the birth of C. V. Riley

Prof. L. M. Peairs, Editor,
Journal of Economic Entomology

It has been suggested that you would be interested in hearing of our plans for celebrating the centennial of the birth of C. V. Riley. The Jefferson National Expansion Memorial is a national historic site established to commemorate the westward movement of the American people. Because Riley made outstanding contributions to the successful advance of agriculture into the West, and also because he did some of his work actually within the area of the Memorial, the National Park Service is arranging a special Riley centennial exhibition to be held in the Museum of National Expansion in St. Louis. The exhibition will outline Riley's career, point out his accomplishments as an artist and his productivity as a scientific writer, and will illustrate his work on two insects important in western agriculture—the Rocky Mountain locust and the cottony cushion scale. It will be opened on the evening of September 22 with a public meeting sponsored jointly by the St. Louis Academy of Science and the Jefferson National Expansion Memorial, the program featuring an illustrated lecture on Riley and his work by Doctor E. P. Meiners of St. Louis. The exhibition will remain on view through October 24. Material for display is being generously loaned by the American Museum of Natural History (Dr. Frank E. Lutz), the University of California (Dr. E. O. Essig), and the Montana State College (Dr. Harlow B. Mills).

Very truly yours,
Julian C. Spotts, Superintendent

The Effect of Winter Soil Temperatures on Emergence of Adults of the Sugar-Beet Wireworm in Cages

M. W. Stone, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Introduction.—Investigations to determine the effect of soil temperatures on the emergence of adults of the sugar-beet wireworm, *Limonius californicus* Mann., in cages were carried on at Alhambra, Calif. between 1931 and 1939 and at Ventura, Calif., between 1940 and 1942.[1] A partial report on the investigations at Alhambra was presented in an earlier publication (Stone 1941). The importance of obtaining accurate and complete information on the time of beginning and on the peak of adult emergence cannot be overemphasized, especially when recommending control measures for wireworms. A knowledge of the time of adult emergence is not only highly important for the proper timing of cultural or chemical practices to destroy eggs, such as cultivating frequently to desiccate the eggs, or using soil fumigants, but it also provides valuable information as to the time for plowing under winter cover crops or bean straw that have been grown or placed on the soil surface to build up the productivity of the soil and to prevent soil erosion. As is indicated by experimental work now in progress, adults of the sugar-beet wireworm are attracted to straw and to winter cover crops; therefore, by proper timing of plowing, it will be possible to avert a build-up of wireworm populations and the consequent serious damage to crops.

Procedure.—To conduct these studies tile cages (6″×24″) made by cementing two 6- by 12-inch drainage tiles end to end were set vertically in the ground 23 inches deep, so that 1 inch remained above the surface for the attachment of screen cages. To prevent escape of the larvae one-half inch of plaster of paris was poured into the bottom of each cage and allowed to harden. Soil of a sandy-loam texture was taken from infested fields and screened, and then placed in the cages and fumigated with carbon disulfide. In June of each year, or about a month before pupation, a total of 25 large mature *Limonius californicus* larvae were buried in each cage between the 6- and 12-inch depths, with a small quantity of corn. Larvae confined in this style of cage pupated normally, being subjected to practically the same conditions of moisture and temperature as prevailed in the field. The cages were irrigated at intervals and prior to emergence were provided with 18-mesh cylindrical, removable screen tops. During the first half of the emergence period the beetles were removed at 12 m. and 5 p.m., but later, when field work was in progress, they were removed at 5 p.m. At each examination the emergence holes were packed with soil so as to prevent possible return of the adults to the soil. A weekly recording soil thermograph was used to record the soil temperature at the 4-inch depth.

Effect of Soil Temperature on Time of Adult Emergence.—In an earlier publication (Stone 1941) the author stated that soil temperature during December and January governed the time of appearance of the beetles, and this was true for the period involved, as it was based on emergence and temperature data obtained during the 4-year period 1932 to 1935, inclusive. Now that records for a 12-year period are available, it appears that soil temperature at the 4-inch depth during the 5-month period, September to January, inclusive, affected the time of the beginning of emergence more than did temperatures during the 2-month period preceding emergence. This fact is shown clearly in the temperature and emergence data in table 1. It is interesting to note that soil temperatures at the 4-inch depth during the 5-month period preceding emergence in 1936, 1938, and 1939 averaged from 2° to 7° F. higher than for the same period in other years. As a result, adults emerged exceptionally early, on January 23, and 24. When the average of the monthly mean temperatures during these 5 months dropped to between 62° and 63.5°, emergence occurred later, in the period January 30 to February 13, and with a further drop to 60°, emergence occurred between February 16 and 24. The

[1] Alhambra is located 30 miles inland and 77 miles east of Ventura, which is on the coast. Although summer temperatures differ, the soil temperatures during the winter months at these two locations differed only slightly.

latest emergence recorded was on March 1 in 1932, and this delayed appearance of the adults was due to extremely low soil temperatures which prevailed during the last 3 months of the 5-month period and throughout February. With the emergence and temperature data now available, it will be possible to predict with some accuracy the time of initial adult emergence in cages.

Table 1.—The date of the beginning of adult emergence of the sugar-beet wireworm from tile cages, as affected by soil temperatures at the 4-inch depth during the period September to January, inclusive.

Year	Date Emergence Began	Average Soil Temperature during					
		Sept.	Oct.	Nov.	Dec.	Jan.	Sept.-Jan., Inclusive
		°F.	°F.	°F.	°F.	°F.	°F.
1939	Jan. 23	85.7	74.8	63.9	58.4	53.0	67.2
1936	23	78.5	71.1	60.9	57.0	57.5	65.0
1938	24	82.8	73.1	60.0	55.6	53.9	65.1
	Average	82.3	73.0	61.6	57.0	54.8	65.8
1935	Jan. 30	75.9	68.2	60.8	55.9	53.3	62.8
1941	31	75.7	70.2	59.4	56.2	54.4	63.2
1942	Feb. 3	75.9	68.2	62.5	56.5	54.6	63.5
1940	6	77.7	68.6	60.7	55.1	55.0	63.4
1934	13	72.4	69.9	61.7	53.0	53.4	62.1
	Average	75.5	69.0	61.0	55.3	54.1	63.0
1937	Feb. 16	78.2	68.3	61.8	52.0	40.8	60.2
1933	20	75.9	66.9	62.7	49.1	48.0	60.5
1931	24	73.2	68.6	59.5	49.9	50.6	60.4
	Average	75.8	67.9	61.3	50.3	46.5	60.4
1932	Mar. 1	78.0	69.3	54.1	47.3	46.0	58.9

DAILY MAXIMUM TEMPERATURES OF SOIL PRECEDING EMERGENCE.—Data presented in table 2 show that the maximum soil temperature at the 4-inch depth usually increased slightly during the week prior to the beginning of emergence of adult males. The most pronounced increase in temperature occurred on the first day of emergence, and this apparently furnished the impetus for the movement of the adults to the surface. The maximum soil temperature on the first day of emergence ranged from 58° F. in 1937 to 70° in 1936, indicating that temperature at this time affects emergence to a less extent than does the temperature earlier in the season.

Despite the fact that in some years adult females emerged later than males, the average maximum soil temperature, 63.5° F., at the 4-inch depth on the first day of emergence was practically the same as the 62.3° recorded for the emergence of males. Temperatures during the 4-day period preceding emergence of females, however, were higher than those for the same period preceding the emergence of males, indicating that the female beetles require slightly higher temperatures.

EMERGENCE OF ADULTS FROM CAGES.—In 1931 emergence of adults of the sugar-beet wireworm began on February 24 and terminated 38 days later, on April 2. Sex records of the adults are not available. Of the 136 adults which emerged, 6 per cent emerged during the week ended February 26, and 23 per cent during the week ended March 5. Higher temperatures prevailed during the week March 6–12 (average 63.6° F.) and, as a result, 37 per cent of the beetles emerged. During the week ended March 19, 26 per cent emerged, followed by 5 per cent the following week and 3 per cent during the week March 27 to April 2.

Starting in 1932, a careful record was kept of the sex of all adults that emerged. The records of male and female emergence at Alhambra, Calif., during the years 1932

to 1939, inclusive, together with the mean soil temperature at the 4-inch depth for each week, are shown graphically in figure 1. Data on emergence at Ventura

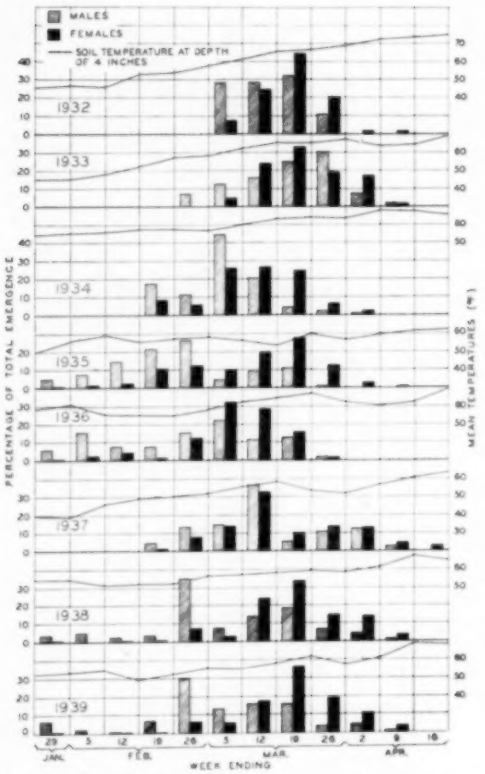

FIG. 1.—Time and rate of emergence, by weeks, of males and females of *Limonius californicus* from tile cages, Alhambra, Calif., 1932–39.

during the years 1940 to 1942, inclusive, are shown graphically in figure 2.

Owing to low soil temperatures during February (average 51° F.) and during the five previous months (average 58.9°), emergence of males in 1932 occurred on March 1 and females on March 4, the latest emergence dates recorded during the 12-year period of these studies. Males were more numerous during the first and second weeks but were surpassed by females in the third week of the emergence period. The peak of emergence for both sexes occurred during the week ended March 19. The male and female emergence periods were the shortest recorded during these studies. Male emergence terminated on March 24, after 24 days, and female emergence on April 3, after 31 days.

In 1933 emergence of males began on February 20 and females on February 28. Males were more numerous during the first 2 weeks of the emergence period but were exceeded in number by the females in the third and later weeks. Most unusual was the fact that the peak of male emergence occurred during the week ended March 26, or 1 week later than the peak of female emergence. Male emergence extended over a period of 44 days and terminated on April 4. Females emerged over a period of 35 days, until April 3.

Emergence in 1934 differed in that both males and females were taken on February 13, the day of initial emergence. As usual, males predominated during the early part of the emergence period, but starting with the fourth week females were more numerous. The peak of female emergence occurred during the week ended March 12 and the male peak was reached the week before. The last male was obtained on April 2 and the last female on March 28. Male emergence extended over a period of 49 days and female emergence, 44 days.

In 1935 both males and females emerged on January 29 and reached a seasonal peak during the week ended March 19. Soil-temperature means at the 4-inch depth for December 1934 and January

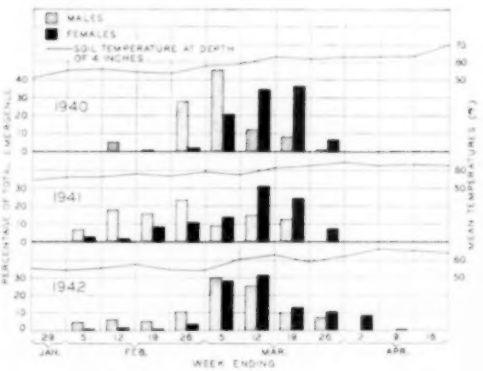

FIG. 2.—Time and rate of emergence, by weeks, of males and females of *Limonius californicus* from tile cages, Ventura, Calif., 1940–42.

1935 were the highest recorded to this date and apparently were responsible for the early appearance of the adults. Soil temperatures during the emergence period, however, were lower than in other years. As a result, the duration of the

emergence period was prolonged. Males exceeded females in number during the first 5 weeks, but the situation was reversed during the sixth and remaining weeks of the emergence period. Male emergence continued over a period of 56 days, until March 25, and female emergence 66 days, until April 4.

Since the beginning of adult-emergence studies in 1932, average soil temperatures at the 4-inch depth for the period September to January, inclusive, have gradually increased each year. Soil temperatures at the 4-inch depth for this period averaged 58.9° F. in 1932, 60.5° in 1933, 62.1° in 1934, 62.8° in 1935, and 65° in 1936. These successive increases in soil temperature have consistently brought on earlier emergences. As compared with 1932, adults emerged 9 days earlier in 1933, 17 days earlier in 1934, 31 days earlier in 1935, and 38 days earlier in 1936. Males emerged on January 23 in 1936 and females on January 26. Intermittent rains accompanied by low soil temperatures during the period January 29 to February 19 retarded emergence, but beginning February 20, higher temperatures prevailed and emergence was accelerated as a result. The peak of male and female emergence occurred during the week ended March 5 and emergence terminated on March 21. Males emerged over a period of 59 days, and females over a 56-day period.

Soil temperatures at the 4-inch depth during January 1937 averaged 40.7° F., the lowest recorded during these studies, and, together with low soil temperatures during December 1936, delayed emergence in 1937. Males emerged on February 16 and females on February 19. There were several heavy rains before and during the emergence period—in fact, 3.92 inches of rain fell in the period February 13 to 15 before emergence occurred. Because of unusually low soil temperatures, very few beetles emerged during the first 2 weeks of the emergence period, but with increased temperatures in the third and fourth weeks, emergence was accelerated. The peak of seasonal emergence for both males and females was reached during the week March 6-12. Male emergence

Table 2.—Dates of emergence of adult sugar-beet wireworms as affected by maximum soil temperatures at the 4-inch depth prior to emergence.

Year	Date Emergence Began	Maximum Soil Temperature on First Day of Emergence	Maximum Soil Temperatures on Days Preceding Emergence					
			First	Second	Third	Fourth	Fifth	Sixth
		°F.	°F.	°F.	°F.	°F.	°F.	°F.
			MALES					
1933	Feb. 20	69	68	67	68	66	67	66
1934	Feb. 13	60	65	64	62	62	60	61
1935	Jan. 30	66	59	62	62	62	65	64
1936	Jan. 23	70	69	68	68	66	62	62
1937	Feb. 16	58	53	52	51	55	51	55
1938	Jan. 24	62	62	60	59	59	60	58
1939	Jan. 23	62	54	51	54	64	65	62
1940	Feb. 6	60	60	60	56	57	57	58
1941	Jan. 31	63	62	64	61	60	63	60
1942	Feb. 3	62	61	59	58	57	57	56
1933–42	—	63.2	61.3	60.7	59.9	60.8	60.7	60.2
			FEMALES					
1933	Feb. 28	71	73	73	72	65	64	68
1934	Feb. 13	60	65	64	62	62	60	61
1935	Jan. 30	66	59	62	62	62	65	64
1936	Jan. 26	69	66	70	70	69	68	68
1937	Feb. 19	61	55	63	58	53	52	51
1938	Jan. 24	62	62	60	59	59	60	58
1939	Jan. 27	58	62	63	64	62	54	51
1940	Feb. 20	63	63	59	56	58	58	58
1941	Jan. 31	63	62	64	61	60	63	60
1942	Feb. 3	62	61	59	58	57	57	56
1933–42	—	63.5	62.8	63.7	62.2	60.7	60.1	59.5

terminated on April 7 and female emergence on April 12, the latest date females were recovered in cages. Males emerged over a period of 51 days and females over a 53-day period.

In 1938 both male and female adults emerged on January 24 and terminated emergence 74 and 71 days later, respectively, on April 7 and 4. This prolonged emergence period, the longest recorded to this date, was the result of heavy rains between January 24 and February 20, at which time only a few of either sex emerged. Soil temperatures were higher beginning in the week February 20–26, and the rate of emergence increased accordingly. The peak of male emergence in 1938 occurred during the week ended February 26 and that of female emergence during the week ended March 19.

In 1939 adult males emerged on January 23, or 1 day earlier than in 1938. The first female emerged on January 27. Cloudy weather, rains, and strong winds were responsible for a retardation in the rate of emergence during the second, third, and fourth weeks. Male emergence, especially, was accelerated when temperatures increased, beginning February 20, and it was the same week, February 20–26, that they reached their seasonal peak. The female peak was not reached until March 19. Both male and female adults terminated emergence on April 6, or 74 and 70 days, respectively, from the time of beginning emergence.

At Ventura, Calif., in 1940 (Fig. 2), male adults began emerging on February 6, reached the peak of emergence during the week ended March 5, and terminated emergence on March 20. Average temperatures of 54.5° and 53.8° F. at the 4-inch depth, together with rains, retarded male emergence during the first 2 weeks but beginning the third week and with higher soil temperatures (average 58.1°), emergence was greatly accelerated. Females appeared on February 20, reached a seasonal peak in the week ended March 19, and terminated emergence on March 23. Males emerged over a period of 44 days, and females, 33 days.

In 1941 male and female beetles began emerging on January 31. The time of initial emergence was apparently unaffected by heavy rains, as the total precipitation during the preceding 3 months was 24.77 inches. There were also heavy rains throughout the emergence period. Male adults exceeded female adults in numbers during the first 4 weeks, but the latter were more numerous during the fifth and remaining weeks. The male seasonal peak of emergence was reached during the week February 20–26, and the female peak during the week March 6–12. Adult males emerged over a period of 47 days, until March 18, while female emergence extended over a period of 52 days, until March 23.

In 1942 adults of the sugar-beet wireworm began emerging on February 3, or 3 days later than in 1941. Apparently neither excess dryness nor an over-abundance of moisture affected the initial appearance of the beetles. The year was extremely dry, as only 6.42 inches of rain fell during the 3-month period preceding emergence, as compared with nearly 25 inches in 1941. Yet emergence in these 2 years occurred on about the same date. As in previous years, males were predominant in number during the first part of the emergence period, but the situation was reversed during the latter part. The peak of male emergence was reached during the week ended March 5 and the female peak in the following week, March 6-12. Males and females emerged over a period of 52 and 61 days in 1942 and terminated emergence on March 26 and April 4, respectively.

LARVAE EMPLOYED AND SEX RATIO OF ADULTS.—Of the 7310 larvae used in these studies, a total of 3282, or 44 per cent, transformed to adults in the ratio of 34 per cent males and 66 per cent fe-

Table 3.—Percentage of emergence as adults and sex ratio of sugar-beet wireworms overwintered in tile emergence cages.

YEAR	LARVAE INTRODUCED	ADULTS RECOVERED	RATIO OF FEMALES TO TOTAL ADULTS
	Number	*Per Cent*	*Per Cent*
1931–32	300	31	70
1932–33	750	24	69
1933–34	560	42	58
1934–35	750	45	68
1935–36	750	54	74
1936–37	450	39	58
1937–38	750	63	68
1938–39	750	51	72
1939–40	750	51	54
1940–41	750	28	58
1941–42	750	54	73
1931–42	7,310	44	66

males (Table 3). Some of the larvae failed to pupate and were recovered later in the cages, others were the victims of cannibalism or died from natural causes. The occurrence of a larger number of females each year was due to the fact that only large mature larvae were selected for burial in the cages for the reason that they were most certain to pupate. Most of these large larvae, as verified by weighings (Stone 1941), transform to adult females, whereas the small larvae transform to males.

SUMMARY.—The reduction of wireworm populations by cultural or chemical practices can be most effectively accomplished by proper timing based on knowledge of the time and peak of adult emergence. Studies conducted over a 12-year period indicated that in sandy-loam soils temperature was the chief factor affecting the time emergence of adults of the sugar-beet wireworm began in cages. Soil temperature at the 4-inch depth during the period September to January, inclusive, was found to be an indicator of the time of appearance of the adults. When temperatures during this period averaged 65° to 67.2° F., emergence began on or before January 24, and when temperatures decreased to averages of 62° to 63.5°, emergence began between January 30 and February 15. With a further decrease in temperature to 60°, emergence began after February 15, and when below 60°, in March. Apparently daily temperatures during the week previous or on the day of emergence are not so important as those earlier in the season. In 1 year emergence occurred when the temperature at the 4-inch depth reached a maximum of 58°, as compared with 66°, 69°, and 70° in other years.

Apparently neither a deficiency nor an excess of soil moisture affected the initial appearance of the beetles, as emergence began on or about the same date when extremes of these conditions prevailed.

Although peaks of male emergence were recorded in each of the weeks February 20 to March 26, the greatest number of males emerged during the week ended March 5. The females were more consistent, as in six of the years the seasonal peak was reached during the week March 13-19, and in four other years during the week ended March 12. Males were always more numerous during the first 2 weeks and in some years during the third, fourth, fifth, and even the sixth week of the emergence period, whereas females were predominant during the remaining weeks. The latest date of male emergence was April 7 and the last female emerged on April 12. Males emerged over a range of from 24 to 74 days and females from 31 to 71 days, and both over an average period of 52 days.

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Sodium Fluoride as an Ant Control[1]

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Sodium fluoride exceeded expectations by far as a control measure against ants at the U. S. Naval Hospital, Pensacola, Florida during May and June 1943. It did all that was promised in Leaflet No. 147 of the U. S. Department of Agriculture and many times more. Applied as a dust to the surface of and slightly within many nests of *Pogonomyrmex badius* (Latr.),[2] *Solenopsis geminata* (F.), *Dorymyrmex pyramicus* (Rog.), *Dorymyrmex pyramicus* var. *flavis* (McCook), *Pheidole dentata* (Mayr), and *Paratrechina longicornis* (Latr.) by means of a small bellows duster, sodium fluoride gave complete control in every instance usually within a day or two with only one application. The success and simplicity of this method indicates that sodium fluoride might well be substituted for fumigants in ant control.—6-18-43.

[1] Approved for publication by Capt. W. W. Hargrave, Medical Officer in Command, U. S. Naval Hospital, Pensacola, Florida.

[2] Determination of all species mentioned was by Dr. M. R. Smith, Division of Insect Identification, Bureau of Entomology and Plant Quarantine, Washington, D. C.

Adherence and Retention of Sulfur on Citrus Foliage

R. L. Busbey, L. B. Howard,[1] and Robert A. Fulton, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Sulfur dust has been used for the control of the citrus thrips, *Scirtothripscitri* (Moult.), the black scale, *Saissetia oleae* (Bern.), and the citricola scale, *Coccus pseudomagnoliarum* (Kuw.), in central and southern California since 1928 (McGregor 1928, 1930). The treatment against these insects involves a number of applications during the season. The dust is usually applied by driving a large double-fishtail duster mounted permanently on a truck between the rows of trees at 3 to 8 miles per hour. The amount of dust applied is controlled by means of a variable orifice in the machine.

From 1938 to 1941 the amount of sulfur deposited by regular commercial dustings and the retention of the material between dustings was studied at the Whittier, Calif., laboratory. During the summer of 1938 and 1939 the deposits were determined in the Cox lemon grove in East Whittier and during 1939, 1940, and 1941 in the Wilson lemon grove in the San Fernando Valley. These groves were selected because of the marked differences in temperature and other climatic conditions. Both groves were being treated for the control of the citrus thrips. In 1939 and 1940 deposits were also determined in the West orange grove in North Whittier Heights.

The sulfur used in these experiments was guaranteed by the manufacturer for 95 per cent to pass through a 325-mesh screen. Sulfur from the same grinding was used for all the plots during the year.

Sampling and Analytical Technique.—The trees selected for sampling were uniform in shape and size, with well-filled foliage at the beginning of the study, and rather centrally located in the sulfur-dusted plot. In exploratory tests a sample consisting of 400 leaf disks 2 sq. cm. in area, taken from 5 or 10 trees, was found to be adequate to reflect the average deposit in the experimental plots. At the beginning of the 1938 season a sample consisted of 80 leaf disks from each of 5 trees, but later it was found preferable to take 40 disks from each of 10 trees, to avoid cutting too much leaf material from 1 tree. Equal numbers of disks were taken from each quadrant, up to a height of about $6\frac{1}{2}$ feet. All samples were taken in duplicate.

The samples were collected with a punch designed to cut the disks and force them directly into a test tube, and thus prevent loss of sulfur in handling (Fulton 1942). The sulfur and the leaf disks were then analyzed according to the following procedure, which was essentially that of Thatcher and Streeter (1925) but modified by Cassil of the Bureau of Entomology and Plant Quarantine:

The leaf disks were transferred to a Soxhlet extractor, and any additional sulfur in the test tube was removed by thorough washing with carbon tetrachloride. The disks were extracted with carbon tetrachloride for 1 hour. The extract was then evaporated to dryness on a steam bath, and the residue in the extraction flask was treated with 25 ml. of concentrated nitric acid, 10 ml. of 60 per cent perchloric acid, and 2 ml. of liquid bromine. An air-cooled condenser was connected to the flask, and the contents were heated for 1 hour on a steam bath. This treatment oxidizes the sulfur to sulfuric acid but does not destroy the organic matter. To accomplish this the flask was then gently heated on a hot plate until all the nitric acid had been expelled and the liquid was colorless. When the white vapors of perchloric acid became visible, the flask was allowed to cool. The contents were then filtered into a 400-ml. beaker and diluted with water to 200 ml. The solution was neutralized with ammonium hydroxide and acidified with 1 ml. of concentrated hydrochloric acid. The sulfate ion was then precipitated with barium chloride, filtered, ignited, and weighed. The sulfur was calculated from the weight of barium sulfate and reported as micrograms per square centimeter of leaf surface.

Cox Lemon Grove, East Whittier.—In the Cox lemon grove 6 applications of sulfur were made in 1938 and 5 in 1939. Approximately 1 pound per tree was used in the first application, $\frac{3}{4}$ pound in the sec-

[1] Now with the Bureau of Agricultural Chemistry and Engineering.

ond, and ½ pound in subsequent applications. The results from 8 pairs of duplicate samples representing 5 trees (1938) showed an average difference of 7.4±7.2 micrograms per square centimeter, and those from 10 pairs representing 10 trees (1939) showed an average difference of 5.2±4.3 micrograms per square centimeter. The deposits are shown in figure 1. In 1938, 0.66 inch of rain fell between the first and second dustings. The rainfall in combination with natural weathering reduced the sulfur from 125 to 29 micrograms per square centimeter. Between the second and third dustings 0.13 inch of rain was recorded, which reduced the sulfur deposit

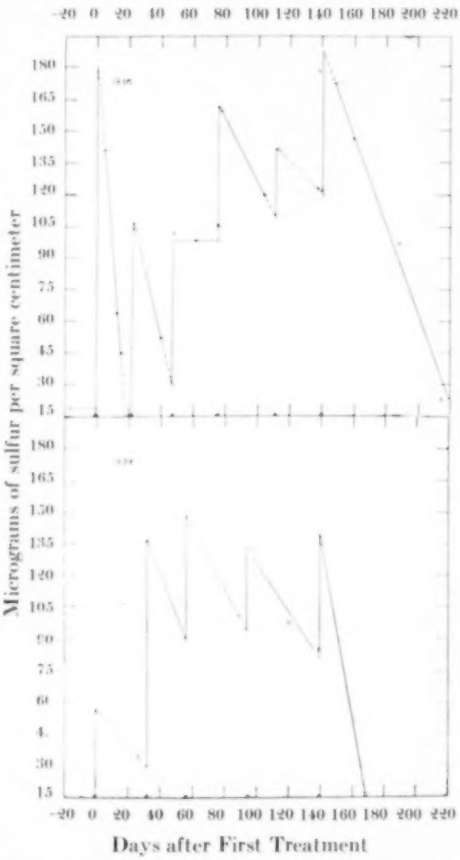

FIG. 1.—Sulfur deposits in Cox lemon grove, Whittier, Calif., 1938 and 1939. In all figures dots along X-axis indicate dustings.

on the leaves from 88 to 35 micrograms per square centimeter. In 1939, 2.12 inches of rain was recorded between the first and second dustings, which reduced the sulfur deposit from 41 to 19 micrograms per square centimeter. No further rain was recorded for the season.

WILSON LEMON GROVE, SAN FERNANDO.—In the Wilson lemon grove six applications of sulfur were made in 1939

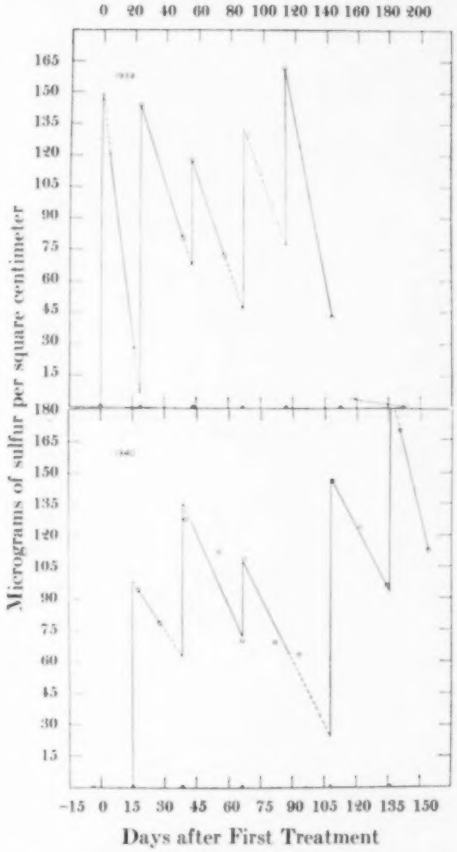

FIG. 2.—Sulfur deposits in Wilson lemon grove, San Fernando, Calif., 1939 and 1940.

(fig. 2). Between the first and second dustings 0.12 inch of rain was recorded, and between the fifth and sixth dustings 0.08 inch. There was a heavy rain immediately after the last dusting before any leaf samples had been taken (indicated by the break in the curve). In 1940 five applications were made. In addition to the usual samples of 40 disks from each of 10 trees, supplementary samples were taken at the top and bottom of 5 other trees within the treated area to determine the distribution of sulfur in different locations of the tree. Between the first and second dustings 0.06 inch of rain was recorded. There was no consistent difference between the samples

taken at the top and bottom, the averages for the seasons being 101.31 and 99.8 micrograms per square centimeter, respectively.

For the 1941 season the regular procedure was changed to study the variation in the amount of sulfur retained by individual trees. One plot was dusted five times with regular dusting sulfur in the usual amounts, and another plot was dusted at the same rate with a mixture of equal quantities of sulfur and talc. The samples consisted of 200 disks from 5 trees selected at random except that no tree was sampled more than three times. This restriction was adopted to avoid cutting too many disks from one tree. Only a trace of rain was recorded. The sulfur deposits are shown in table 1.

Table 1.—Average sulfur deposits in Wilson lemon grove, San Fernando, Calif., 1941.

Days After First Treatment	Micrograms of Sulfur per Square Centimeter			
	Sulfur Plot		Sulfur-Talc Plot	
	Average	Standard Deviation	Average	Standard Deviation
−10	0	—	0	—
0[1]	110.0	21.7	85.5	14.1
25	51.1	8.7	51.2	16.3
27	200.0	24.6	129.0	24.4
53	76.4	13.9	88.1	16.8
54	246.4	35.5	94.5	4.5
80	92.0	27.9	55.5	10.5
83	183.4	40.0	98.1	22.4
109	105.6	29.1	61.8	11.8
110	127.3	12.7	88.7	7.4

[1] First dusting May 16, 1941.

WEST ORANGE GROVE, NORTH WHITTIER HEIGHTS.—In 1939 and 1940 sulfur deposits were determined in the West orange grove in North Whittier Heights that was receiving experimental dusting with sulfur to control the black scale. Only two applications were made with approximately 0.9 pound per tree at each application. In 1939 no rainfall was recorded. In 1940, 0.03 inch of rain was recorded between the first and second dustings. The results are shown in table 2.

DISCUSSION.—The amount of sulfur deposited on the foliage varied considerably at different times in the season, possibly owing to varying humidity, wind drift, and so forth, at the time of application. There was no obvious difference in the adherence or rate of weathering between the lemon groves in Whittier and those in San Fernando in spite of the marked difference in climate. In general the maximum temperature is much higher and the humidity lower in San Fernando Valley than in the Whittier area. The San Fernando area is also subjected to severe winds throughout the season. There was no consistent difference in the amount of sulfur deposited at the top and bottom of the lemon trees. There were marked differences in the deposits on individual trees, which might be due to variations in the rate of progress of the duster, the flow of the sulfur, gusts of wind, and so forth. The deposits persisted well under the dry weather normally encountered in southern California during the dusting season, but, as might be expected, the sulfur was almost completely removed by a heavy rain.

SUMMARY.—Sulfur deposits were determined on lemon and orange foliage in different sections of southern California. No difference was detected in the rate of weathering under the different climatic conditions, or in the amount of sulfur deposited at the top and bottom of the tree. However, there was a marked variation in the deposits of individual trees. Initial applications of sulfur ranged from 41 to 125 micrograms per square centimeter, depending on weather conditions at the time of the dusting. Subsequent applications also showed a wide variation of deposits. Heavy rains removed a large portion of the sulfur on citrus foliage.

Table 2.—Sulfur deposits in West orange grove, North Whittier Heights, Calif.

1939		1940	
Days after First Treatment[1]	Micrograms of Sulfur per Square Centimeter[2]	Days after First Treatment[3]	Micrograms of Sulfur per Square Centimeter[2]
−23	0.0; 0.3	−7	0.0; 0.0
0	45.0; 48.6	0	61.0; 67.3
23	141.2; 126.5	12	45.8; 40.4
		17	46.3; 47.1
		21	113.1; 124.4
		41	125.5; 125.0
		61	86.7; 90.8
		84	85.7; 79.2

[1] First treatment applied June 3 and the second June 24.
[2] The two figures for each examination represent duplicate determinations.
[3] First treatment applied May 15 and the second June 5.

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Concentration of HCN and Mortality of *Cryptolaemus montrouzieri* in the Foliage of a Fumigated Tree and on the Ground Beneath

CHAS. F. HENDERSON, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Chemical control practices often have an important influence on the natural enemies of species of insects other than those for which the treatments are being applied. As pointed out by Smith & Armitage (1931, pp. 57–58), when the black scale, *Saissetia oleae* (Bern.), is fumigated with hydrocyanic acid gas in the late summer and fall, the treatment greatly disturbs the activities of the predaceous beetle *Cryptolaemus montrouzieri* Muls., which has at that time built up to such numbers as to control mealybug infestations. According to these investigators, the first shock of the gas apparently caused many of the beetles to drop to the ground. Here they were exposed to the lower concentrations of the fumigant, and many escaped death, whereas, so far as observed, all those adults that lodged in the tree, where they were exposed to the full concentration of gas over the entire fumigation period, were killed.

Woglum (1912), working with the two common ladybird beetles *Coccinella californica* Mann. and *Hippodamia convergens* Guér., found that these beetles were stupefied by the gas and that the insects on the ground survived the treatment more readily than those toward the top of the tree.

The purpose of the present investigation was to determine whether there was an appreciable difference between the mortality of adult *Cryptolaemus* in the foliage of a tree and that on the ground beneath when concentrations of hydrocyanic acid gas such as those employed for the control of the California red scale, *Aonidiella aurantii* (Mask.), were used. In these tests recently emerged beetles were caged in 14-mesh screen cages and placed at random in different locations within the foliage of the tree and on the ground beneath. The tests were conducted from October 11, 1940, to April 8, 1942. Some of the experiments were conducted in an orange tree covered with a metal tent form, whereas others were made in lemon trees taken at random in a nearby grove.

SOURCE OF INSECTS USED IN TESTS.—Since adult *Cryptolaemus* beetles reared under field conditions were difficult to collect in sufficient numbers, insectary-reared beetles were used in all the tests reported in this paper.

To compare the mortality of insects reared in the insectary with some collected in the field, beetles from the two sources were put in screen cages and fumigated with different dosages of hydrocyanic acid gas. In one test the beetles were suspended in the tree being fumigated and in the other they were placed on the ground beneath.

In the first test 70.5 ± 3.4 per cent of the insectary-reared insects were killed, as compared with 65.0 ± 4.0 per cent of those that were collected in the field. In the second test the figures were 82.0 ± 4.4 and 84.5 ± 3.0 per cent, respectively. Under the conditions of this experiment there was no significant difference in mortality between insects reared in the insectary and those collected in the field.

STUPEFACTION OF BEETLES.—To determine the time necessary to cause *Cryptolaemus* adults to drop, beetles were exposed in a laboratory fumigation chamber to various constant concentrations of cyanide gas for a period of 5 minutes. The beetles were confined in a screen cage,

[1] R. L. Busbey made various laboratory tests, and T. A. Kendall provided the test insects.

and soon after becoming stupefied they dropped into a pan, which could be observed through a window in the fumigation chamber. The time elapsing between the introduction of the gas and the dropping of each beetle was recorded. The summarized results of this test are shown in fig. 1.

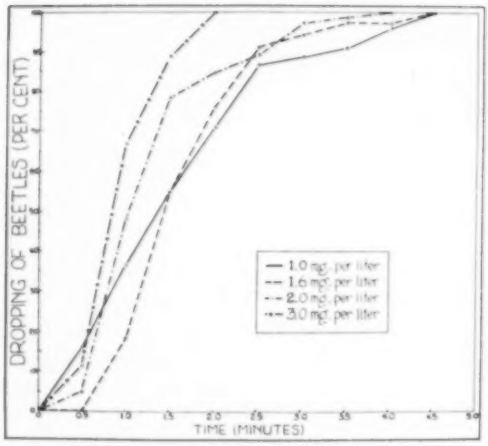

FIG. 1.—The time elapsing between the introduction of different constant concentrations of hydrocyanic acid gas and the dropping of adults of *Cryptolaemus montrouzieri* from a cage into a pan beneath.

With a concentration of 1.0 mg. of hydrocyanic acid gas per liter all the beetles that dropped into the pan had done so within 4.5 minutes, whereas with a concentration of 3.0 mg. only 2 minutes were required. Approximately 10 per cent of all the beetles did not release their hold on the screen, but remained in the cage throughout the exposure period. Since peak concentrations in field fumigations are well above 1.0 mg. per liter, even when low dosages are applied, the indications are that most of the beetles would spend the greater part of the standard 45-minute exposure period on the ground beneath the tree being fumigated.

EFFECT OF WIRE CAGE.—To hold the beetles at various levels in the foliage of a fumigated tree and on the ground beneath during the exposure period, it was necessary to confine them in screen cages. Tests were therefore conducted to determine whether a difference in mortality occurred between beetles exposed to gas concentrations within the cages and those exposed to similar concentrations outside. Small, 14-mesh, copper-screen cages were placed in an orange tree and on the ground. Since past experiments had indicated that oxidation of the wire might cause some variation in mortality, all the cages were treated with lacquer and thoroughly dried before use, and this treatment probably had some influence on the uniformity of the results. The insects were fastened to triangular paper points by means of rubber cement, and half of them were distributed in the cages and the others were attached to flat strips of copper screen outside the cages. The tree was covered with a fumigation tent, and different dosages of hydrocyanic acid were applied. The results are shown in table 1.

Table 1.—Mortality of adults of *Cryptolaemus montrouzieri* when exposed to concentrations of hydrocyanic acid gas inside and outside of copper-screen cages located in the tree and on the ground.

DATE	DOSAGE, CC. PER 100 CU. FT.	POSITION OF SAMPLE	MEAN MORTALITY OF BEETLES PER CAGE, NUMBER[1]	
			Outside Cage	Inside Cage
Mar. 23	10	In tree	8.53 ± 0.29	8.27 ± 0.28
26	13	On ground	4.13 ± 0.36	4.07 ± 0.46
31	11	In tree	6.87 ± 0.35	7.00 ± 0.38
		On ground	5.20 ± 0.52	6.00 ± 0.41
Mean for all dosages and positions			6.18 ± 0.29	6.33 ± 0.28

[1] Based on 15 cages of 10 beetles each.

Mortality of beetles inside and outside the cages did not differ significantly. This was true for each test and when the results for all tests were grouped together and compared. It is obvious, therefore, that a 14-mesh screen cage has no appreciable influence on the mortality of the confined beetles. A higher mortality occurred in the tree than on the ground both inside and outside the cages.

METHODS OF DETERMINING MORTALITY AND GAS CONCENTRATION.—In conducting fumigation tests in the field the beetles were confined in 14-mesh screen cages that were randomly distributed in the foliage of the tree and on the ground beneath. In some of the tests mortality records were taken by transferring the beetles from the cages to paper plates approximately 12 hours after treatment and determining the number that remained 24 hours after treatment. It was assumed that beetles having sufficient strength to leave the plates would have a fair chance of surviving the treatment. In other tests the beetles were held in the screen cages until the final mortality counts were taken

Table 2.—Concentration of hydrocyanic acid gas and mortality of adults of *Cryptolaemus montrouzieri* caged in the tree and on the ground when the vaporized hydrocyanic acid method of application was used.

Date	Dosage, Cc. per 100 Cu. Ft.	Mean Temperature, °F.	Average Gas Concentration, Mg. per Liter[1]		Mean Mortality of Beetles, Per Cent		
			In Tree	On Ground	In Tree	On Ground	Difference
Oct. 11	16	72.5	1.02	0.84	94.0±1.9	92.0±1.7	2.0
15[2]	16	61.0	1.43	1.32	94.8±1.2	94.2±1.7	.6
22	16	60.5	1.12	.84	93.0±3.0	90.0±3.7	3.0
28	18	57.0	1.20	1.13	78.0±3.3	71.4±5.9	6.6
Jan. 31	24	53.5	1.25	1.03	93.3±1.1	91.2±2.8	2.1
Mar. 19	22	54.0	—	—	94.0±1.4	89.4±1.3	4.6*
Apr. 8	22	56.0	—	—	90.7±1.5	87.4±1.7	3.3
Mean (weighted)			1.20	1.03	91.2	87.9	

[1] For first 25 minutes of 45-minute exposure period.
[2] Soil wet.
* Significant, $P < .05$.

approximately 24 hours after the fumigation.

Gas concentrations were determined by drawing a liter of air from various locations in the tree, and from positions 1 inch above the soil surface beneath the tree, at specified intervals throughout an exposure period of 45 minutes. The liter samples were later analyzed for the amount of hydrocyanic acid gas present. In some of the tests a single sampling tube was placed in the tree and one on the ground, whereas in other tests several tubes were placed in both situations.

METHODS OF APPLICATION.—The behavior of HCN under a fumigation tent has been discussed by Fulton *et al.* (1941). In the present studies gas concentrations and mortalities of *Cryptolaemus* adults were determined in the foliage of the tree and on the ground beneath. In seven tests the fumigations were made with vaporized hydrocyanic acid gas, employing one of the commercial vaporizers now in general use. In this machine hydrocyanic acid is heated to a temperature sufficient to cause vaporization before entrance into the nozzle. The pot method was used in three tests, sodium cyanide being added to dilute sulfuric acid in a fumigation pot underneath the tent. Two tests were made with a liquid hydrocyanic acid applicator in which the liquid is pumped from a reservoir to a nozzle that is held under the tent. One test was made with a liquid applicator equipped with nozzles capable of producing

Table 3.—Concentration of hydrocyanic acid gas and mortality of adults of *Cryptolaemus montrouzieri* caged in the tree and on the ground when the pot and liquid methods of application were used.

Date	Dosage, Cc. per 100 Cu. Ft. or Equivalent	Mean Temperature, °F.	Average Gas Concentration, Mg. per Liter[1]		Mean Mortality of Beetles, Per Cent		
			In Tree	On Ground	In Tree	On Ground	Difference
			Pot Method				
Nov. 15	18[2]	68.5	0.85	0.89	87.5±4.2	82.5±6.5	5.0
19	18[2]	53.0	1.31	1.15	88.2±1.9	84.8±2.9	3.4
22	18[2]	50.5	1.31	1.26	—	—	—
Mean (weighted)			1.16	1.10	87.8	83.6	
			Liquid Method				
Nov. 8	18	61.5	1.01	2.63[3]	83.5±2.9	97.5±0.8	14.0**
19	14	56.0	—	—	52.6±3.5	76.6±4.9	24.0**
Mean (weighted)					68.9	87.6	

[1] For first 25 minutes of 45-minute exposure period.
[2] Sodium cyanide and sulfuric acid at rate equivalent to an 18-cc. dosage of liquid hydrocyanic acid.
[3] Concentrations were actually higher, since initial titrations were not completed.
** Highly significant, $P < .01$.

finer atomization than the standard machine.

RESULTS OBTAINED WITH THE VARIOUS METHODS.—The results with the vaporized hydrocyanic acid method are summarized in table 2. In this table, as in all subsequent tables, the mean percentages with their standard errors were determined from a series of individual percentages.

When the vaporized hydrocyanic acid method was used, concentrations of hydrocyanic acid gas were somewhat higher in the tree than on the ground. In the first five tests there was an average gas concentration of 1.20 mg. per liter in the tree as compared with 1.03 mg. per liter on the ground. The use of this method also resulted in a slightly higher mortality of *Cryptolaemus* in the tree than on the ground. Although only one test resulted in a significant difference in mortality between the two levels, the differences were always in the same direction, and when all the tests were grouped together and compared, the mean difference was highly significant. An average of 3.3 per cent more beetles were killed in the tree than on the ground beneath, but at the mortality levels encountered this difference was difficult to demonstrate with the size of sample used. In the combined tests 1,724 beetles had been caged in the tree and 1,732 on the ground.

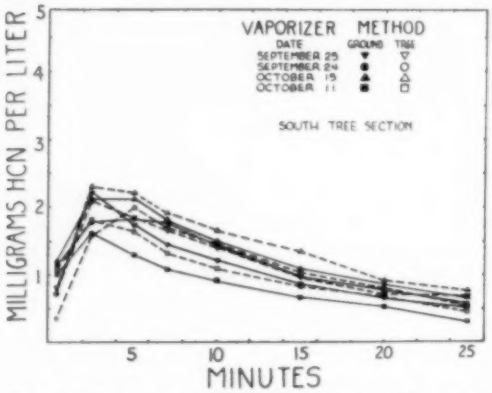

FIG. 2.—Concentrations of hydrocyanic acid gas in a tree and on the ground beneath when the vaporized hydrocyanic acid method was used. Solid lines represent concentrations at ground level and broken lines those in the tree.

When the pot method of application was used, concentrations and mortalities did not differ greatly from those obtained through the use of the vaporized hydrocyanic acid method. The mortality of the beetles was again slightly higher in the tree than on the ground, but the difference was not significant (table 3).

When the liquid method was used, together with the standard applicator, concentrations and mortalities were significantly higher on the ground than in the tree (table 3). In another test, in which a 14-cc. dosage and an applicator expecially equipped with nozzles capable of producing finer atomization than the standard machine were used, the mortality was 55.6 ± 4.8 per cent in the tree and 64.6 ± 5.7 per cent on the ground. The finer atomization would result in a smaller difference between the gas concentration in the tree and that on the ground beneath. If a standard applicator had been used, the difference between the mortalities at the two levels would probably have been greater.

EFFECT OF SOIL MOISTURE.—To determine the effect of soil moisture on the mortality of *Cryptolaemus* in the tree and on the ground, the soil beneath an orange tree was thoroughly saturated with water on the afternoon preceding fumigation. This test was conducted on October 15, and the results may be compared with those obtained on October 11 and 22, when the soil was comparatively dry (table 2). It is apparent that no appreciable differences in mortality occurred between the two positions on any of these three dates.

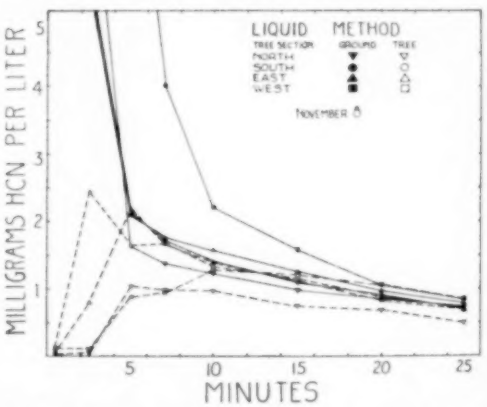

FIG. 3.—Concentrations of hydrocyanic acid gas in a tree and on the ground beneath when the liquid method of applying the fumigant was used. Solid lines represent concentrations at ground level and broken lines those in the tree.

TYPES OF CONCENTRATION CURVES OBTAINED.—There were relatively small dif-

ferences between the mortality of adult *Cryptolaemus* in the tree and that on the ground beneath when the vaporized hydrocyanic acid and pot methods of application were used, although the mean gas concentrations were more than 10 per cent higher in the tree. It was thought that mean concentrations might not be indicative of expected kills because of some difference in the time that peak concentrations were reached in the tree and on the ground after the introduction of the gas. Consequently, comparisons were made of typical concentration curves for the various fumigation tests, and those for the vaporized hydrocyanic acid and liquid method of application are shown in figs. 2 and 3.

the two levels. In this test there was a mortality of 93.3 per cent in the tree and 91.2 per cent on the ground. The average gas concentrations were 1.25 mg. per liter and 1.03 mg. per liter in the two positions, respectively.

As previously stated, concentrations and mortalities were found to be higher on the ground than in the tree when the liquid method was used. Concentration curves obtained from samples taken from four positions each in the tree and on the ground are shown in fig. 3. It is obvious that during the first part of the exposure period concentrations were extremely high on the grouud, but later they decreased.

Concentrations of hydrocyanic acid gas at various intervals during fumigation with

Table 4.—Mortality of adults of *Cryptolaemus montrouzieri* caged in a tree and on the ground when fumigated with a low dosage of approximately 11 cc. of hydrocyanic acid vaporized per 100 cubic feet.

Date	Number of Cages	Number of Beetles per Cage	Mean Temperature, °F.	Mean Mortality of Beetles, Per Cent		
				In Tree	On Ground	Difference
Nov. 7	6	30	69.0	56.1±4.9	48.9±8.1	7.2
Mar. 16	16	22	52.0	62.2±2.3	52.3±3.3	9.9*
Apr. 21	16	22	50.0	74.7±2.2	59.7±3.5	15.0*
Mean (weighted)				66.5	54.9	

* Significant, $P < .05$.

In tests with the vaporized hydrocyanic acid method made on different dates between September 24 and October 15, 1940, the types of concentration curves obtained from sampling in the foliage of the tree and 1 inch above the ground were not greatly different (fig. 2). Although in general the curves were similar, gas concentrations were higher in the tree than on the ground almost throughout the exposure period. The average concentration in the tree for the four tests was 1.20 mg. per liter as compared with 1.12 mg. per liter on the ground.

In a test with the vaporized hydrocyanic acid method in which sampling tubes were placed at five locations in the tree and five on the ground, four of the concentrations were higher in the tree than on the ground during the first 5-minute period, but thereafter the curves were not greatly different. It is probable that under field conditions many of the beetles spend part of this peak period in the foliage of the tree and do not fall to the ground until concentrations become more uniform at the pot method were very similar to those obtained by using the vaporized hydrocyanic acid method, being somewhat higher in the tree than on the ground.

DIFFERENTIAL EFFECT AT LOW MORTALITY LEVELS.—Dosage-mortality curves were made from tests in which constant concentrations, and decreasing concentrations such as obtained in field fumigations, were used in a laboratory fumigation chamber. These curves indicated that in fumigations causing mortalities of approximately 80 per cent or over the rate of mortality began to level off.

Such mortalities of adult *Cryptolaemus* were obtained in all tests where commercial dosages of 16 to 24 cc., as used against the California red scale, were applied in the field against caged insects. Since these mortalities occurred at points on the time-mortality curve where the mortality rate began to level off, it was expected that the difference in gas concentrations observed (table 2) would be associated with relatively small differences in the mortality of adult *Cryptolae-*

mus. To determine whether greater differences in mortality would occur in the tree and on the ground at lower mortality levels, tests were conducted in which beetles were subjected to low dosages, approximately 11 cc., of hydrocyanic acid vaporized per 100 cubic feet. The results are given in table 4.

When a low dosage of vaporized hydrocyanic acid was used, mortalities were higher in the tree than on the ground. In the test conducted on November 7 there was no significant difference between the kills obtained at the two levels. In the tests on March 16 and April 21 larger samples were used, and each test resulted in significantly higher mortalities in the tree than on the ground. When all the tests were combined there was a mean difference of 11.6 per cent in mortality between beetles caged in the tree and those on the ground.

To compare the differences in mortality of adult beetles in the tree and on the ground at the various mortality levels, all tests in which various dosages of cyanide were applied by the vaporized hydrocyanic acid and pot methods, were combined. When full commercial dosages of hydrocyanic acid were applied, the mean mortality at the two levels was 88.7 per cent and the difference ranged between 0.6 and 6.6 per cent, with a mean of 3.4 per cent. When a low dosage was used, the difference in mortality at the two levels ranged between 7.2 and 15.0 per cent, with a mean of 11.6 per cent. Since such a low dosage is never used commercially, it is evident that during regular field fumigations no appreciable differences in mortality would result whether the beetles remained in the tree or dropped to the ground.

SUMMARY.—The fumigation of the California red scale, *Aonidiella aurantii* (Mask.), with hydrocyanic acid gas has considerable effect on populations of the predaceous beetle *Cryptolaemus montrouzieri* Muls. At dosages of 16 to 24 cc. per 100 cubic feet approximately 90 per cent of the adult beetles caged in the tree and on the ground beneath were found to be killed.

When the vaporized hydrocyanic acid and pot methods of application were used, concentrations of hydrocyanic acid gas and mortalities were higher in the tree than on the soil surface, although the differences in mortality were small. The liquid method resulted in significantly higher gas concentrations and mortalities on the ground than in the tree.

The amount of soil moisture did not appreciably influence the mortality of beetles held in the tree and on the ground.

No great differences were observed between the concentrations in the tree and those on the ground when the vaporized hydrocyanic acid and pot methods of application were used. When the liquid method was employed, concentrations were extremely high on the ground during the first part of the exposure period, but later they decreased.

The relative differences between mortalities occurring in the tree and those occurring on the ground decreased as the average mortality level increased. With regular commercial dosages of hydrocyanic acid no appreciable mortality differences would result whether the beetles remained in the tree or dropped to the ground during exposure to the gas.—4-8-43.

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Bordeaux and Other Sprays for Control of Japanese Beetle

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The experiments described in this paper were an outgrowth of the necessity for protecting a planting of several thousand young elm trees and seedlings from the attacks of the adult Japanese beetle, *Popillia japonica* Newm. C. H. Hadley (1940) has succinctly summarized all previous work and the current opinions on the subject of Japanese beetle repellents in the simple statement, "The foliage and fruit of susceptible food plants can be protected from beetle attack by the application of sprays which leave a deposit repellent to the beetle." In many instances the covering of even ornamentals with a temporary coating is not objectionable. Such treatment may often be necessary, especially in nurseries, where large numbers of susceptible plants are grown in one place, and where the presence of a residue is of no immediate esthetic importance. A number of investigators have called attention to the repellency of lead arsenate and of lime to the adult Japanese beetles, and Van Leeuwen (1932) made special detailed studies of the reactions of the beetles to deposits of these materials. Other workers have studied means of improving the adhesiveness of lime, and the effect of various adhesives on its repellency (Metzger & Lipp 1936; Guy & J. B. Schmitt 1937).

In 1939, Mr. Lyle E. Hagmann called our attention to the fact that grapes sprayed with a 4-4-50 bordeaux mixture had remained virtually free from Japanese beetle injury. Since bordeaux mixture with lead arsenate has greater resistance to weathering than either alone, this combination was used throughout our elm plantings. The results were very satisfactory. However, there was no body of comparative data of sufficient scope to show how this spray compared directly with certain other sprays that had been recommended for use against the Japanese beetle. Experiments were planned with the object of comparing several sprays composed of materials commonly used by fruit-growers and nurserymen, several commercial products advertised as Japanese beetle sprays, and several chemicals suggested by their manufacturers for trial as possible Japanese beetle repellents.

Table 1.—List of sprays used in Japanese beetle experiments in 1941 and 1942.

Formula Number	Name or Composition	Amounts Used per 100 Gallons of Water
1.	Copper sulfate Lime Lead arsenate (bordeaux mixture)	8 lbs. 8 lbs. 6 lbs.
2.	Same as No. 1, but without lead arsenate (bordeaux mixture)	
3.	Lead arsenate Wheat flour	6 lbs. 4 lbs.
4.	Aluminum sulfate Lime (14 lbs. in 1941)	3 lbs. 20 lbs.
5.	*Smack*	
6.	*Smack* with *Smack Repellent*	
7.	*Newco*	
8.	*Japrocide*	
10.	*Du Pont Japanese Beetle Spray*, made previous to 1940.	
11.	Derris powder (4% rotenone content) *Grasselli Spreader-sticker*	4 lbs. 4 oz.
12.	Nicotine sulfate Bentonite	1 pint 4 lbs.
14.	Copper cyanamide Linseed oil	6 lbs. 1½ pints
16.	Ferric dimethyldithiocarbamate (*Fermate*) Bentonite	2 lbs. 2 lbs.
17.	Phenothiazine	2 lbs.
18.	Lead arsenate *Grasselli Spreader-sticker*	6 lbs. 3 oz.
19.	*Du Pont Japanese Beetle Spray* (new in 1942)	
22.	Phenothiazine Bentonite	2 lbs. 2 lbs.
24.	Phthalonitrile *Vatsol*	2 lbs. 2½ lbs.
26.	*Styx*	

In table 1, are listed only the formulae which were used in the experiments from which definite indications of results were obtained. Several of the sprays were tested during two seasons, others during one season only. Most of them did not receive adequate trials. Several were unquestionably effective and several gave

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definitely unfavorable indications. The majority were between the two extremes. The latter included most of the proprietary "Japanese beetle remedies," the majority of which consisted of a rotenone-bearing dust with a chemically inert diluent to act as a spreader and adhesive. Sprays 5, 6, 7, 8, 10, 19 and 26 were proprietary mixtures, recommended by their manufacturers for use against the Japanese beetle, and were mixed and used according to directions on the labels.

FIG. 1.—View of elm planting in arboretum, showing relative size of trees and method of spraying used in 1941.

The list of formulae was purposely heterogeneous, and in appraising the results no attempt was made to distinguish specific effects on the beetles. It should be mentioned that the manufacturers of the proprietary sprays do not, in general, claim a lasting power sufficient to stand up under the conditions of some of the tests. The primary purpose of our experiments was to determine which of the several sprays would best protect the plants, with a minimum of labor, regardless of how it achieved its effects. This was judged from the condition of the plants at the end of the season, or after a given period, and by counts of beetles during the season.

FIELD TESTS ON ELMS IN BOYCE THOMPSON ARBORETUM IN 1941.—The trees (*Ulmus americana L.*) were five years old and ranged up to 12 feet in height. Twelve sprays were used, namely, numbers 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12 and 14. The planting was laid out in groups of 12 trees so that each spray was represented once in each group. The sprays in each group were randomized. Thus, there were 144 sprayed trees, divided into 12 groups of 12 trees each, and using 12 formulae. True "check" trees were not included. The planting was sprayed on July 10 and 11, when the first beetles were coming to the trees, and little or no feeding had occurred on the few trees where beetles had already alighted. The sprays were applied with a 3-gallon compressed-air hand-sprayer with a 6-foot boom equipped with an adjustable nozzle. A view of the planting and method of spraying are shown in figure 1.

The size of the planting and the size of the trees made it necessary to have a large beetle population in order to obtain counts and injury figures which might show differences sufficiently large for satisfactory analysis. The beetle population was smaller than was anticipated, but would probably have been sufficient had not the depredations of cankerworms and elm leaf beetles in many instances obscured the Japanese beetle injury or rendered trees unsuitable for Japanese beetle feeding. Therefore, the information from this experiment is, at best, indicative only of possible trends, although the results were corroborated later in more precise tests.

BEETLE COUNTS.—On the third day after spraying, the fewest beetles were observed on the trees sprayed with bordeaux and lead arsenate, bordeaux alone, and lead arsenate and wheat flour. Six complete beetle counts were made, on July 14, 16, 24, 29, 30 and August 4. The peak of beetle attack occurred about July 24, two weeks after spraying, when 2,495 beetles were counted. On this date, the trees sprayed with bordeaux mixture and lead arsenate had the lowest count, differing by an average of more than 30 from their nearest competitors. The next lowest counts were on the trees sprayed with bordeaux alone, lead arsenate and wheat flour, and 2 proprietary sprays. After July 24, the beetle population had diminished to such an extent that the later counts were not considered significant.

FOLIAGE INJURY.—Owing to the size of the trees and to the foliage injuries caused by other insects it was considered best to evaluate the relative amounts of Japanese beetle injury at the end of a certain period by estimates rather than by actual counts of injured leaves. A complete examination was made on August 6. The injury was graded as severe (3.0); medium (2.0); light (1.0); almost none (0.5); and none (0.0). Three treatments averaged less than 1, namely bordeaux mixture with lead arsenate, lead arsenate and wheat flour, and one proprietary spray.

TESTS ON POTTED ELMS AT THE BOYCE THOMPSON FARM.—It was planned that parallel experiments on smaller trees would furnish the details that were missing in the larger experiment. The trees used at the Boyce Thompson farm were 3- to 4-year-old trees growing in 12-quart pails. They averaged around 5 feet in height. At the time the tests were begun the beetles had already started to attack these trees. However, 50 trees which had escaped attack were segregated in a large cage, and thus kept free from beetle injury until they were sprayed. The remaining trees, which were not protected until they were sprayed, had already suffered a small amount of injury.

On July 23, 49 of the protected trees and 49 of the unprotected trees were moved into position and sprayed, using six sprays and a check for each set of trees. Thus, there were seven of each type of tree for each of the 7 treatments. Each set was arranged as a latin square. The sprays used were formulae 1, 2, 11, 16, 17, 18, and check. The squares were designated latin squares *A* and *B*, and were identical in every respect except that *A* included only trees which had no beetle injury at the time of spraying, and *B* was composed of trees which already had a slight amount of injury. On July 26, another latin square of 49 trees, Square *C*, was arranged and sprayed, using formulae 1, 6, 7, 8, 11, 19, and checks. These trees also had already been exposed to beetle attack.

Bait containers from Japanese beetle traps were placed in squares *A* and *B* to draw a more plentiful supply of beetles to the locations, a suggestion furnished by the Japanese Beetle Laboratory of the U. S. Bureau of Entomology and Plant Quarantine, at Moorestown, N. J.

Beetle counts were made at intervals, as in the arboretum, and at the end of the experiment all the leaves on all the trees in the three latin squares were examined and classified according to the amount of Japanese beetle injury.

BEETLE COUNTS.—On August 8, two weeks after spraying, 388 beetles were counted in a rapid survey of latin square *A*. The averages per tree are given in table 2.

Table 2.—Beetle counts in latin square A, August 8.

FORMULA	AVERAGE NUMBER OF BEETLES PER TREE
1	0.28
16	4.00
11	4.30
18	4.40
2	7.00
17	25.00
Ck	10.40

Although undue importance should not be attached to an analysis of figures taken from a population momentarily so changeable as a group of adult Japanese beetles, it is interesting to note that the odds were better than 19 to 1 that the number 1 spray reduced the beetle counts and that the number 17 spray may have increased them. The square root transformation of the beetle counts was made before analysis of variance was computed, as suggested by Snedecor (1940). There is shown here the same trend that appeared later in the leaf examinations in more definite form, and which also appeared in the beetle counts on the larger trees in the arboretum.[1]

In latin squares *A* and *B*, the beetles were counted on ten different days between July 24 and August 8. From these figures, the formulae were ranked for each count, first rank being given to the formula with the smallest number of beetles, second rank to the one with the next highest, and so on. In the ten counts on square A, Formula 1 ranked first (*i.e.*, best) 7 times, second twice, and third once; and in square *B* formula 1 ranked first 7 times, second once and third twice.

FOLIAGE INJURY.—The leaf examinations were made on August 20, 21, 22.

[1] Acknowledgment is here made of the generous help and advice of Dr. W. J. Youden and Dr. F. E. Denny in planning experiments and interpreting results.

A summary of the results is presented in table 3. The data given are based on percentages of injured leaves, including all the leaves that were injured in any way by the beetles. The formulae used in each square are listed in the ascending order of the per cents of injured leaves.

Table 3.—Results of leaf examination in latin squares.

SQUARE A.

FORMULA	NO. LEAVES	PER CENT INJURED LEAVES
1	4133	5.29
16	3539	11.44
11	4550	12.30
18	3299	13.06
2	2781	14.53
17	3253	18.23
Ck	2116	26.37

SQUARE B.

FORMULA	NO. LEAVES	PER CENT INJURED LEAVES
2	1469	17.22
11	2070	20.87
18	1949	25.19
1	1876	25.48
17	2487	35.34
16	2093	37.08
Ck	2062	43.84

SQUARE C.

FORMULA	NO. LEAVES	PER CENT INJURED LEAVES
11	2340	18.21
1	1458	20.57
6	1728	21.82
8	1671	23.58
19	2351	24.42
7	1816	26.16
Ck	1924	36.28

Inasmuch as square *A* furnished the most reliable information, since the trees in it had no injury previous to spraying, the data from this square were the only figures subjected to further study. Analysis of the angular transformations of the percentages of injured leaves (Snedecor, 1940) showed that formula 1 was not only better than the checks, but was also significantly better than any other formula, except possibly number 16, where the odds were slightly less than 19 to 1. There were no other significant differences among the formulae.

The fact that the value for the two lead arsenate sprays combined (Numbers 1 and 18) is not certainly better than the checks leads to the inference that it was not the lead arsenate itself that was effective, but rather the adhesive used; or more specifically, it was the *combination* of lead arsenate with bordeaux mixture. Added strength is given to this inference when it is noted that bordeaux mixture by itself, in this experiment, was not distinctive.

EXPERIMENTS in 1942; YONKERS, N. Y.—In 1942 it was planned to test the same materials tested in 1941 but in different plat arrangements and in some instances on different plants. A number of additional sprays were used, and variations of the original formulae, suggested by the data from 1941, were tried. In general, the results of the work in 1942 were disappointing, due to the several exceptionally severe rains and the extended rainy periods in July, the critical month for such work in Westchester county. These conditions made it necessary to repeat treatments which took considerable time to apply, and therefore reduced the number of experiments and the number and accuracy of the observations. Furthermore, fewer beetles were present in the plantings than in 1941. Of ten experiments, including a large-scale test on 210 six-year old elms on which a power-sprayer was used, and smaller tests with bayberry plants and smartweed, only Experiment 8 produced results which could be satisfactorily interpreted. This experiment is described below.

TESTS ON BAYBERRY.—Bayberry (*Myrica carolinensis* Mill.) bushes which had been transplanted into a large cage to protect them from Japanese beetles were sprayed on August 8 with the following sprays: Numbers 2, 4, 16, 19, 22, and 26. After the spray had dried, seven twigs were clipped from each of the sprayed branches, and each twig was placed in a 2-oz. bottle which was filled with water and sphagnum moss, and plugged with cotton. Seven unsprayed twigs were handled in the same manner. The 49 bottles of twigs were arranged in a 7×7 latin square by suspending each bottle from a wire framework at a height of 4.5 feet. The manner of arrangement of the bottles is pictured in figure 2. (The photograph was made when another similar experiment was in operation; Ex-

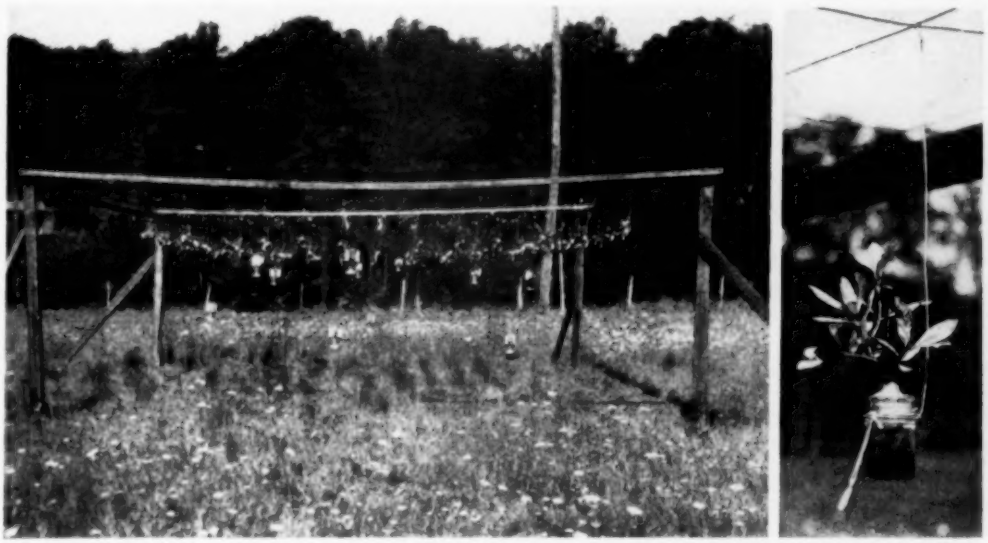

FIG. 2.—Arrangement of bottles of bayberry twigs, as used in Experiment 8, in 1942. At right, one of the bottle and twig units in greater detail.

periment 8 included fewer units and fewer beetle traps). Bait containers from Japanese beetle traps were placed at the corners, at the sides, and in the center of the square to draw the beetles into the area. After the first day, it was observed that the beetles were active among the twigs in all parts of the square during periods of favorable weather.

FOLIAGE INJURY.—In the leaf examinations, which were made on the fifth day, each leaf was rated according to the estimated amount of beetle injury. This was expressed in per cent of leaf surface injured, for each leaf. From these data were calculated, for each spray, the numbers of leaves and percentages of leaves which were "more than slightly injured" (the totals of the leaves classified as having injury of "light to 10 per cent," and higher). The original data are summarized in table 4. An analysis of the angular transformations of the percentages indicated that three sprays, namely bordeaux mixture (2) *Fermate* with bentonite (16), and phenothiazine with bentonite (22) were very significantly better than the checks. The differences between the 3 best sprays (bordeaux mixture, *Fermate* with bentonite, and phenothiazine with bentonite) and the other three sprays were significant. The differences between bordeaux mixture and the 2 next best sprays (*Fermate* with bentonite and phenothiazine with bentonite) were slightly less than the differences required for significance at odds of 19 to 1.

Table 4.—Japanese beetle injury to bayberry leaves in experiment 8.

FORMULA	TOTAL NUMBER LEAVES	NUMBER OF LEAVES MORE THAN SLIGHTLY INJURED
2	176	31
4	158	106
16	115	35
19	166	130
22	187	68
26	190	118
Ck	163	131

DISCUSSION.—By a series of experiments designed so that the results of any one experiment would supplement the results of all the others, it was hoped to evaluate a number of spray mixtures used to prevent damage to plants by adult Japanese beetles. Although each experiment was a unit in itself, all the formulae were not used in all of them, and several experiments which were required to carry over the comparisons from one to another, or which were to be the key experiments for less complete tests, failed to produce sufficient data for satisfactory analysis. Thus it happened that experimental con-

ditions precluded a definite conclusion with all but three or four of the formulae tested.

The rotenone-bearing sprays were not expected to withstand weathering for the duration of the periods of the tests and although the early beetle counts may have indicated differences, the present paper is concerned only with the ultimate maximum benefit that was obtained. Even with this statement in mind it may be noted that the temporary relief from intensive beetle feeding which some of the rotenone sprays afforded was reflected in the fact that with almost every recommended material, the sprayed plants were better than the checks with respect to foliage injury from the beetles at the end of the experiments.

None of the trees or plants showed foliage injury that could be definitely ascribed to the sprays.

It is interesting to note that phenothiazine alone (Formula 17) as used in latin square *A* in 1941 was of no benefit, but that when combined with bentonite, as in experiment 8 in 1942, favorable results occurred. It is probable that the newer "conditioned" or micronized phenothiazine would produce even more favorable results. Guy & Dietz (1939) also mentioned that phenothiazine had shown results which merited further trials, although in their tests it was not so good as tetramethylthiuram disulfide (*Dupont Japanese Beetle Spray*).

Pierpont (1939), who also used elms as test plants, reported less favorable results with aluminum sulfate and lime than with lead arsenate, derris or tetramethylthiuram disulfide. However, he reported severe foliage injury with lead arsenate and wheat flour. Although this did not occur in our tests, the combination of bordeaux mixture with lead arsenate is regarded as much safer.

Of all the sprays tested, bordeaux mixture alone was common to each of the experiments in which significant observations were made. In the experiments on the larger planted elms in the arboretum, fewer beetles were counted on the trees sprayed with bordeaux alone than on any others except those sprayed with bordeaux and lead arsenate, but statistical analysis of the foliage injury did not distinguish them from several other groups. In the latin square experiment with potted elms, bordeaux mixture alone was not significantly better than several other sprays, after 3 weeks, but bordeaux plus lead arsenate was very significantly better than any other. In the latin square with bayberry twigs, after a 5-day test, bordeaux alone was better than any other spray, including aluminum sulfate and lime (20-pound formula). In this experiment, bordeaux with lead arsenate was not used. In all the experiments in which bordeaux with lead arsenate was used it was superior to bordeaux alone, lead arsenate alone (*i.e.* without bordeaux, but with wheat flour in one experiment and *Grasselli Spreader-sticker* in another), to aluminum sulfate and lime, and to all other sprays tested, both in initial repellency and in lasting power. Phenothiazine with bentonite showed promise, as did *Fermate* with bentonite.

CONCLUSION.—Bordeaux mixture (4-4-50) with lead arsenate (6 pounds per 100 gallons) proved to be the best of several sprays used for the protection of elms and other plants against attack by the adult Japanese beetle over a period of several weeks during two successive summers. Bordeaux alone was also an effective repellent, but it does not leave so heavy nor so durable a residue. One application of the combination of bordeaux and lead arsenate afforded good protection for three weeks and more in 1941. The number of applications that should be made in a given season would depend upon the amount of rainfall and consequent weathering of the spray residue.

Phenothiazine with bentonite and *Fermate* with bentonite compared favorably with bordeaux mixture in several tests. If these sprays continue to show promise, or can be improved, in more extensive tests, the choice may be resolved into a question of individual preference for the type of residue left by each—bluish with bordeaux and blackish or brownish with *Fermate* and phenothiazine.—2-8-43.

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Basic Lead Arsenate: Its Effect on Peach Trees and Compatibility with Various Chemicals

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Since ortho arsenic acid, H_3AsO_4 $1/2H_2O$, the parent compound from which the arsenates of lead used for insecticidal purposes are derived, has three replaceable hydrogen atoms in its molecule, a corresponding number of lead ortho arsenates are possible by the substitution of one, two or three hydrogens, giving rise to mono lead arsenate, $PbH_4(AsO_4)_2$; dilead arsenate, $PbHAsO_4$; and trilead arsenate, $Pb_3(AsO_4)_2$. McDonnell & Smith (1917) have shown that several lead hydroxy arsenates can also be formed. One of these hydroxy compounds, $Pb_4(PbOH)(AsO_4)_3$ H_2O, can be readily manufactured in practically pure form and is generally referred to as basic lead arsenate. Of the three ortho arsenates, the dilead arsenate, commonly called acid lead arsenate and known in industry as "standard lead arsenate," is at present universally used as a stomach poison. On the other hand, the basic lead arsenate has been, heretofore, only sparingly employed. As to their chemical differences, acid lead arsenate contains 21.6 per cent As and 59.7 per cent Pb, whereas basic lead arsenate contains 15.1 per cent As and 69.6 per cent Pb, or approximately 30 per cent less arsenic and 15 per cent more lead.

The main reason why basic lead arsenate has not come into wide use is because it possesses lower toxicity to chewing insects than the acid lead arsenate, as was shown by Scott & Siegler (1915) on fall webworms; Lovett and Robinson (1917) on tent caterpillars; Wilson (1919) on Colorado potato beetles; Cook & McIndoo (1923) on silk worms, fall webworms, tent caterpillars, grasshoppers and potato beetles; Leach (1926) and Fleming (1942) on Japanese beetle larvae; Snapp (1930) on plum curculio, and Bohart & Mallis (1942) on pill bugs. However, laboratory tests by McAlister & Van Leeuwen (1930) show only slight differences in toxicity to newly hatched codling moth larvae between basic and acid lead arsenate. Furthermore on walnut trees in California, where acid lead arsenate produces severe foliage injury, Quayle (1926) and Boyce (1935) report effective control of codling moth with 4 to 5 pounds of basic lead arsenate per 100 gallons of spray. The lower toxicity may be ascribed perhaps first, to its lower arsenic content and second, to its being less digestible within the gut of the insects, as suggested by Campbell & Lukens (1931) on silk worms. On the other hand, acid lead arsenate decomposes more readily than basic lead arsenate when in contact with spray ingredients, releasing water soluble arsenic, often in amounts sufficient to cause varying degrees of foliage injury, especially on arsenic sensitive plants as was shown by Clinton & Britton (1912); Fernald & Bourne (1922); Swingle *et al.* (1923); Smith (1923); Ginsburg (1927, 1937, 1940) and others.

Of fruit trees, the peach is one of the most sensitive to arsenical injury. This plant can tolerate only a very limited number of acid lead arsenate sprays during one growing season, at concentrations of two pounds per 100 gallons and only with excessive amounts of hydrated lime as a corrective. It is on this and similar arsenic sensitive plants that basic lead arsenate is at times substituted for acid lead arsenate, especially in the California coastal fog area where the atmosphere is laden with moisture containing appreciable quantities of chlorides (Tucker 1934),

[1] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

carried by onshore winds. In New Jersey, as well as in other eastern states, the seasonal occurrence of peach injury from acid lead arsenate sprays offers a serious problem to orchardists as well as to entomologists and horticulturists. Recent experiments in Pennsylvania conducted by Steiner & Worthley (1941), indicate that basic lead arsenate proved practically noninjurious to peach trees and in concentrations of four pounds per 100 gallons was not considerably inferior to two pounds of acid lead arsenate in controlling plum curculio. Preliminary field tests in New Jersey have produced similar results.

In view of the awakened interest in basic lead arsenate, it was deemed important to study this chemical under New Jersey conditions. The purpose of the preliminary investigation here reported was twofold. First, to determine the effect of basic lead arsenate on peach trees. Second, to determine the compatibility of basic lead arsenate with various chemicals, usually present in insecticide and fungicide spray mixtures, either as necessary ingredients or as impurities. In order to secure definite comparisons between acid lead arsenates and basic lead arsenate, the two arsenicals were tested simultaneously in all the experiments.

Table 1.—Composition of spray mixtures and arsenical injury to peach trees.

Tree No.	Spray Composition in Lbs. per 100 Gals.			Number of Sprays Applied	Injury Observed
	Basic Lead Arsenate	Acid Lead Arsenate	Hydrated Lime		
1	—	2	—	3	Severe injury.
2	—	2	8	3	Severe injury.
3	—	2	16	7	Appreciable injury, partial defoliation.
4	2	—	0	7	None
5	2	—	8	7	None
6	2	—	16	7	None
7	4	—	0	3	None
8	4	—	8	3	None
9	4	—	16	3	None

MATERIALS AND METHODS.—To accomplish the first objective, field experiments were conducted during 1942 on seven year old peach trees, Fire Glow variety, located in the Entomology test orchard. A series of seven sprays were applied between May 12 and August 27. The sprays, a total of nine different mixtures, consisted of two and four pounds of lead arsenate with eight pounds and with sixteen pounds of hydrated lime, and without lime, per 100 gallons of water. About half of one tree was sprayed for each treatment, the other half serving as check. Frequent observations for foliage and twig injuries were made throughout the season. Arsenical injury to peach trees is fully described by Haenseler & Martin (1925). On leaves it generally occurs as brown, circular areas, or as narrow strips of dead tissue along the margin, often followed by premature defoliation. On wood it appears as necrotic areas on older nodes of the new growth, and as cankers on the bearing wood, causing splitting of the bark and gummosis. The composition of the spray mixtures and observations on arsenical injury are given in table 1.

To accomplish the second objective, several groups of compounds which are normally present in various spray waters; in fungicide and insecticide preparations and in spreaders and stickers, as well as other chemicals which have been shown in previous experiments, Ginsburg (1940), to decompose acid lead arsenate were selected for testing. The formation of water soluble arsenic was taken as the criterion for decomposition of the lead arsenate. In order to obtain a direct comparison of the two arsenicals, both the acid and basic lead arsenates were tested under the same conditions. Lead arsenate in proportions of 2 and 2.5 gms. (equivalent to approximately 3 and 4 pounds per 100 gallons), mixed with various concentrations of the selected chemicals in 500 cc. distilled water was allowed to stand for about 24 hours at room temperature with frequent shaking. The mixtures were then filtered and the soluble arsenic in the filtrates was determined as As_2O_5 by the standard iodine method, as outlined in the Official Methods (1940).

FIELD TESTS.—Foliage injury from acid lead arsenate sprays began to show after the second application on trees 1 and 2 (Table 1), receiving no lime and only 8 pounds of lime respectively. After the third application the injury on these two trees became severe, causing heavy defoliation and spraying was discontinued. Later in the season gummosis developed on the bearing wood, being especially pronounced on tree 1. On tree 3, receiving acid lead arsenate with 16 pounds of hydrated lime, injury on foliage began to show late in July after the fifth spray and increased in severity during August and

Table 2.—Soluble arsenic formed from *basic* lead arsenate, as compared with *acid* lead arsenate, when mixed with different chemicals in 500 cc. of distilled water and shaken for 24 hours.

Mixture No.	Chemicals Tested			Basic Lead Arsenate		Acid Lead Arsenate	
	Name	Formula	Concentration Per cent	Pounds per 100 Gallons	Per Cent As_2O_5	Pounds per 100 Gallons	Per Cent As_2O_5
1	Calcium carbonate	$CaCO_3$	0.19	3	0.00	—	—
2	Calcium carbonate	$CaCO_3$	0.38	3	0.00	3	1.55
3	Magnesium carbonate	$MgCO_3$	0.38	3	0.00	3	5.51
4	Sodium carbonate	Na_2CO_3	0.12	3	0.24	3	13.40
5	Sodium bicarbonate	$NaHCO_3$	0.25	3	0.13	3	4.29
6	Lime sulfur	—Dilution	1–50	3	0.25	3	0.38
7	Lime sulfur	—Dilution	1–100	3	0.35	3	6.75
8	Lime sulfur	—Dilution	1–200	3	0.35	3	20.33
9	Lime sulfur	—Dilution	1–400	3	0.65	3	10.59
10	Hard water		600 PPM[1]	4	0.04	3	2.08
11	Hard water		1200 PPM[1]	4	0.04	3	3.41
12	Cocoanut oil soap	—	0.05	4	0.12	3	1.52
13	Cocoanut oil soap	—	0.10	4	0.37	3	2.83
14	Cocoanut oil soap	—	0.25	4	0.37	3	4.88
15	Sodium silicate	Na_2SiO_3	0.12	4	0.40	3	3.33
16	Sodium silicate	Na_2SiO_3	0.25	4	0.40	3	4.94
17	Sodium phosphate, mono	NaH_2PO_4	0.25	4	0.46	3	5.80
18	Sodium phosphate, di	Na_2HPO_4	0.25	4	0.81	3	7.35
19	Sodium phosphate, tri	Na_3PO_4	0.25	4	0.46	3	14.91
20	Aluminum sulfate	$Al_2(SO_4)_3$	0.12	4	0.20	3	0.44
21	Aluminum sulfate	$Al_2(SO_4)_3$	0.25	4	0.28	3	0.60
22	Sodium sulfate	Na_2SO_4	0.25	4	0.08	3	0.37
23	Copper sulfate	$CuSO_4$	0.25	4	0.10	3	0.16
24	Zinc sulfate	$ZnSO_4$	0.25	4	0.07	3	0.07
25	Sodium sulfite	Na_2SO_3	0.25	4	0.23	3	7.17
26	Sodium chloride	NaCl	0.25	4	0.08	3	2.43
27	Calcium chloride	$CaCl_2$	0.25	4	0.09	3	2.67
28	Calcium phosphate, mono	$Ca(H_2PO_4)_2$	0.25	4	0.07	3	5.97
29	Sodium nitrate	$NaNO_3$	0.25	4	0.07	3	0.53
30	Borax	$Na_2B_4O_7$	0.25	4	0.09	3	9.40
31	Boric acid	H_3BO_3	0.25	4	0.09	3	0.15
32	Sodium sulfide, mono	Na_2S	0.25	4	9.45	3	32.48
33	Sodium sulfide, penta	Na_2S_5	0.25	4	2.50	3	28.78
34	Hydrogen sulfide	H_2S	0.01	4	0.53	3	4.96
35	Hydrogen sulfide	H_2S	0.02	4	4.00	3	10.50
36	Hydrogen sulfide	H_2S	0.04	4	9.63	3	15.18
37	(Check) Lead arsenate only	—	—	4	0.08		
38	(Check) Lead arsenate only	—	—	—	—	3	0.17

[1] Calculated as calcium carbonate.

September, developing a considerable amount of cankering but no gummosis.

BASIC LEAD ARSENATE.—None of the typical symptoms of arsenical injury appeared on any one of the peach trees sprayed with basic lead arsenate, regardless of whether or not lime was added. Even on trees 7, 8 and 9, where 4 pounds of basic lead arsenate were used, the foliage and young wood appeared normal and did not differ in any way from the check trees. It should be mentioned here that seven sprays during one season as applied in these experiments is excessive and entirely uncalled for in insect control on peaches. In New Jersey, generally two and not more than three lead arsenate sprays are applied on peaches during one season. Since no injury occurred from seven applications of 2 pounds and from three applications of 4 pounds basic lead arsenate, these results indicate that this arsenical offers a much safer spray on peaches than the acid lead arsenate.

LABORATORY EXPERIMENTS.—A comparison of the data in table 2, where results from the laboratory tests are presented, brings out the following information. If 0.75 per cent water soluble arsenic, allowed by the Federal Insecticide Act for commercial lead arsenate, should be taken as a standard for comparing the decomposition of the two arsenicals, the basic lead arsenate is vastly more stable than is the

acid lead arsenate. Of some 25 chemicals tested, most of which may be found either in different waters used by farmers for spraying or as ingredient in combined insecticides, fungicides, spreaders, stickers, correctives, etc., only three, namely sodium phosphate, hydrogen sulfide and sodium sulfide, have increased soluble arsenic in excess of the above amount in the case of basic lead arsenate, whereas in the case of acid lead arsenate, 18 exceeded the 0.75 per cent limit.

Notable differences in the degree of decomposition of the two arsenates occurred with the following groups of compounds: Carbonates, lime sulfur, soap, hard waters, silicates and borax. None of the compounds from these groups formed appreciable amounts of soluble arsenic when mixed with basic lead arsenate, while each one of them produced comparatively large percentages of soluble arsenic when mixed with acid lead arsenate, ranging from 1.55 per cent for $CaCO_3$, 20.33 per cent with lime sulfur and 32.48 per cent for sodium sulfide.

Table 3.—Decomposition of basic and acid arsenates of lead in waters of different H-ion concentrations.

Test No.	pH of Solution	Per Cent Soluble As_2O_5	
		Basic Lead Arsenate	Acid Lead Arsenate
60	1.1	4.84	12.18
61	1.8	0.48	1.20
62	2.0	0.12	1.32
63	2.6	0.12	0.42
64	3.0	0.09	0.37
65	3.3	0.08	0.24
66	4.4	0.08	0.24
67[3]	6.0[1,2]	0.08	0.21
68	7.5	0.08	0.23
69	8.5	0.08	0.26
70	9.6	0.08	0.83
71	10.4	0.09	2.64
72	11.2	0.09	11.41
73	11.7	0.40	16.24
74	12.1	2.47	20.45

[1] Stable pH range for acid lead arsenate.
[2] Stable pH range for basic lead arsenate.
[3] Check, distilled water.

It appears, therefore, that the lack of arsenical injury to peach trees from basic lead arsenate may be due primarily, if not entirely, to the high degree of stability of this arsenical in spray mixture.

HYDROGEN ION CONCENTRATION.—Since solutions of the chemicals here tested varied in pH values, based on previous experiments by Ginsburg (1940), from 3.5 for aluminum sulfate to 11.4 for sodium sulfide, the writer became interested to ascertain the influence of H-ion concentration on the rate of decomposition of the two lead arsenates. Accordingly, solutions ranging in pH values from 1.1 to 12.1, as determined by the Beckman pH meter, were prepared, hydrochloric acid being used to adjust the acid range and sodium hydroxide for the alkaline range. Soluble arsenic formed in these solutions from acid and basic arsenates of lead, using approximately 3 pounds of the arsenical per 100 gallons, was determined by the usual procedure. The results presented in table 3 show that basic lead arsenate remained stable in solutions ranging in pH from 2.0 to 11.2, giving virtually no increases in soluble arsenic above that found in the check. On the other hand, the acid lead arsenate was stable in a much narrower pH range, namely between 3.3 to 8.5. It is also evident from the data in the table, that even at H-ion concentrations where both arsenates have decomposed, the amount of soluble arsenic is greater for the acid than for the basic arsenate. Thus, at pH 1.1 the soluble As_2O_5 was 4.84 per cent for the basic lead arsenate and 12.18 per cent for the acid lead arsenate. Again, in solutions of pH 12.1 the acid compound formed 20.45 per cent, whereas the basic arsenate gave only 2.47 per cent soluble arsenic.

Whether or not the relationships between the two arsenates and H-ion concentration in regard to soluble arsenic production here exhibited will hold for other sets of solutions of comparable pH values, especially in the presence of various buffers present in spray mixtures, these limited experiments do not warrant broad conclusions. However, the writer feels that this series of tests may serve as additional confirmation of the higher stability of basic lead arsenate in the presence of chloride and sodium ions, as compared with acid lead arsenate.

In general, the results from this preliminary investigation warrant field experiments with basic lead arsenate on different varieties of peach trees and perhaps on other arsenic sensitive plants in order to determine the concentration of this, apparently safe, arsenical required to produce efficient field control of chewing insects infesting these plants, as compared

with the present standard recommendations of acid lead arsenate.

SUMMARY AND CONCLUSIONS.—Field and laboratory experiments were conducted with sprays containing basic lead arsenate to determine its effect on foliage and its stability in the presence of various chemicals as compared with the acid lead arsenate. In the field, young peach trees were sprayed with basic lead arsenate, with and without hydrated lime, from 3 to 7 times during one growing season and observations for arsenical injury were made. In the laboratory, the effect of various chemicals and of solutions with different H-ion concentrations on the decomposition of basic lead arsenate, as indicated by the formation of water soluble arsenic, was studied in comparison with acid lead arsenate.

The results suggest the following conclusions. Unlike acid lead arsenate, basic lead arsenate does not release water soluble arsenic when mixed with various spray ingredients such as lime sulfur, soaps, hard waters, carbonates, silicates, borates and chlorides.

Basic lead arsenate remained virtually stable in solutions ranging in pH from 2.0 to 11.2, whereas acid lead arsenate was stable only in a pH range of 3.3 to 8.5.

Peach trees showed no arsenical injury after seven successive sprays of basic lead arsenate, whereas only two sprays of acid lead arsenate caused foliage and twig injuries.

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Evaluation of Sodium Fluoride as a Stomach Poison and as a Contact Insecticide Against the Roach *Periplaneta americana* L.[1]

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Sodium fluoride has long been recommended as the standard insecticide for cockroach control. The exact method by which the roach is killed has never been positively analyzed. Evidence has been presented which showed that NaF could act as either a contact insecticide or a stomach poison. Data presented herein are an effort to demonstrate, with the American roach, the mode of action for this common insecticide.

Although Shafer (1915) performed experiments in which roaches were killed by the contact effects of NaF, he concluded that the primary lethal effect came through stomach poison action since the roach ingested poison as it cleaned its appendages after having walked through the insecticide. Hockneyos (1933), working with *Blatta orientalis*, also showed that NaF could act as a contact poison, but he concluded that because of the low coefficient of absorption, the contact effect was of no practical importance in roach control. Munger & Siegler (1937) tried to feed American roaches baits which contained NaF, but they experienced difficulty in getting the roaches to eat, and death was slow to occur. They also reported that NaF could serve as a contact agent. Sweetman (1941) sealed the mouth parts of a small sample of roaches, *Periplaneta americana*, and found that when these roaches were dusted with NaF, they died within 24 hours.

Table 1.—Number of days which roaches lived after feeding on poisoned starch as compared with starved control roaches.

Per Cent NaF	Male		Female		Mean
	Mean	Range	Mean	Range	
7.5	3.3	2–7	3.8	1–8	3.5
5.0	3.3	1–5	3.6	1–7	3.4
2.5	3.5	1–10	6.5	2–11	5.0
1.0	5.9	2–11	7.0	1–11	6.5
Control	10.8	6–11	10.5	2–11	10.7

Adult, laboratory-reared specimens of the American roach, *Periplaneta americana* L., were used as test animals in all of the experiments described below.

NaF as a Stomach Poison.—To determine the effects of NaF as a stomach poison, roaches were given access to starch paste which contained either 1, 2.5, 5 or 7.5 per cent NaF. Poisoned starch paste at each of these NaF concentrations was fed to 20 males and 20 females. Forty roaches were used as control animals and were not fed, but had access to water, throughout the entire 10-day observation period. These controls were starved so as to produce a set of data comparable to that from roaches presented poisoned food, *if* the latter refused to eat and began to die from starvation. Individual roaches were caged in 250 cc. glasses and were starved for three days prior to exposure to the moistened NaF-starch mixtures. Small samples of the paste were placed in the lower angle of the glass container, where the bottom met the vertical side of the glass. This position eliminated some possibilities of the roach walking through the paste. The starch was dampened daily so that the roaches would be more tempted to feed throughout the observation period. No other source of water was provided. The insects were observed for a ten day period following the initial exposure to poisoned food. To prevent complications from contact effects all individuals which appeared to have walked in the poisoned starch to an excessive degree were eliminated from the experiment. Enough extra individual tests were set up to have a full complement of 20 males and 20 females for each set.

Table 1 presents data for control and experimental animals. Figures represent the number of days that elapsed before death was recorded. If a roach lived throughout the ten day observation period, the number of days was recorded as 11; if it was found dead on the second day,

[1] Journal Paper No. *J-1105* of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 372.
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the time was recorded as two days. Since one male control and one female control animal died during the observation period, the means for controls do not quite average 11 days.

As would be expected, the rapidity of toxic action increased with higher NaF percentages. However, there was a leveling off at the 5 and 7.5 per cent levels. This may be partially explained by the fact that the roaches did not feed as readily upon the starch with greater amounts of NaF and thus could go several days without eating before hunger forced them to a fatal intake of food. Or, it may be that 5 per cent is near the maximum fatal dosage which the roaches need to ingest in order to be killed. In another series of experiments (unpublished data) when roaches were examined at autopsy after one day exposures to colored NaF-starch paste, it was observed that the number of insects which failed to feed was increased as the percentage of NaF was raised. A more important fact, however, was that many which had ingested NaF were alive and active after 24 hours or more. Munger & Siegler (1937) had previously reported difficulty in getting roaches to eat poisoned food. Their experience prompted the use of starved controls in our experiments. Table 1 shows that female roaches lived significantly longer than males when fed NaF-starch mixtures. To summarize, it may be concluded that, for the American roach, although NaF can, and does, act as a stomach poison, the onset of death is slow and may not occur until several days after ingestion.

NaF AS CONTACT POISON.—The Effects of NaF as a contact poison were next studied. In this series of experiments an effort was made to determine whether the cleaning of appendages was a contributing factor to the death which occurred following a period in which the roach was allowed to walk in pure NaF dust. In order to do this, a known amount of the poison was dusted evenly over the bottom of a battery jar, six inches in diameter. A roach was then placed on the dust and allowed to run about through the NaF for 15 seconds. The insect was then captured, isolated, and observed for a period of five days. Half of the roaches were allowed to clean their antennae and tarsi. The other group had the mouth parts tightly sealed with cellulose acetate so that they had no opportunity to ingest NaF from their appendages. Since this latter group could not eat, all roaches were starved throughout the observation period. As evidenced by the unsealed control roaches, starvation was not a factor in the death of the experimental insects. (Table 2.) Three strengths of NaF were tested. In one series, a two-gram sample of pure NaF was dusted into the battery jar; in a second series, one gram was used; and in the third, 0.5 gram was mixed with 0.5 gram of talc. The talc was necessary in order to spread this small NaF sample satisfactorily. Twenty males and an equal number of females were exposed to each NaF treatment; 10 males and 10 females had sealed mouth parts.

Initially, the effects of the cellulose acetate were checked. A group of 20 roaches with sealed mouth parts was compared to a similar number which

Table 2.—Survival of adult American roaches after walking on NaF.

NaF Dosage in Grams	Mouth Parts not Sealed				Mouth Parts Sealed			
	Male		Female		Male		Female	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
2.0	21.6	12- 36	28.8	12- 72	20.4	12–29	21.6	12- 29
1.0	22.8	12- 36	26.4	12- 60	24.0	12–29	33.6	12- 44
0.5	60.0	24–120	106.8	72–132	46.8	12–73	97.2	44–132
Mean	34.8		54.0		30.4		50.8	
Control[1]	126.0	96–132	132.0	132–132	103.2	12–132	106.2	36–132

[1] Hours for control not corrected.

Table 3.—Milligrams of NaF per gram of roach and rate at which death occurred.

NaF Dosage	Male		Female	
	Mgm/gm of Roach	Hours Until Death	Mgm/gm of Roach	Hours Until Death
2 gm.	12.9	12	7.1	24
	10.4	24	6.0	12
	9.3	12	5.4	12
	4.1	24	3.8	24
	3.4	24	3.2	24
mean	8.0	19.2	5.1	19.2
1 gm.	8.6	24	10.9	12
	4.7	12	10.3	12
	3.8	24	5.3	60
	2.8	36	4.3	12
	1.7	12	2.7	24
mean	4.3	21.6	6.7	24.0
0.5 gm. (In 0.5 gm. talc)	2.3	48	1.7	132
	2.0	48	1.6	72
	1.6	60	1.4	132
	1.5	84	1.3	72
	0.9	120	1.0	132
mean	1.7	73.2	1.4	108.0
Mean for 15 Insects	4.7	38.0	4.4	50.4

had unsealed mouth parts, but which were starved during the 5-day observation period. (See "control" in table 2.) When data from these two control groups were analyzed, it was found that the average number of days lived by the two groups differed significantly; those with sealed mouth parts living only 82 per cent as long as the others. Since the cellulose acetate had a deleterious effect upon the roaches, when used to seal their mouth parts, it was necessary to use a correction factor in recording the death of those experimental insects whose mouth parts had been sealed. Thus, it was assumed that a roach lived only 82 per cent as long as it would have lived if the cellulose acetate cement had not been used.

Table 2 presents data for the three series of NaF treatments. The figures represent the number of hours which elapsed before death was recorded.

For those roaches with sealed mouth parts, the numbers are corrected ones. The insects were checked at 12-hour intervals for five days. If a roach was alive at the end of 5 days, its time was recorded as 132 hours.

As indicated in table 2, survival of roaches increased as the amount of NaF was decreased. This trend was more obvious when the actual weight of NaF collected by a roach was known. Thirty roaches in the above experiment were weighed both before and after they had walked through the NaF. Thus it was possible to calculate milligrams of NaF collected per gram of roach for each individual. Mouth parts of these insects were not sealed. Table 3 reports the quantities of NaF collected, and the number of hours that the roach lived after it was exposed to the poison. The roaches were checked at 12 hour intervals for five days. If they were alive at the end of 5 days, the time was recorded as 132 hours.

These data indicate a correlation between the amount of NaF and the rapidity with which death occurred. This was more evident for the dosages of less than 4 milligrams of NaF per gram of body weight. Larger quantities usually produced death within 12 or 24 hours time. Figure 1 presents the same data in another form. The shift in trend at about 4

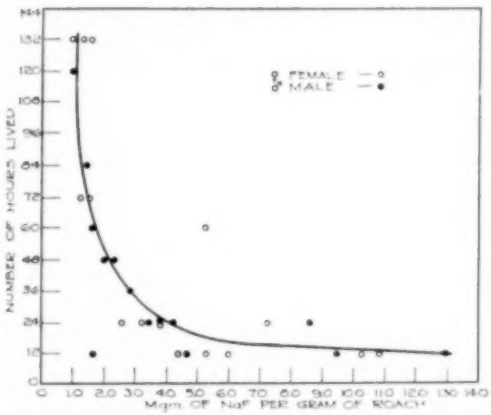

FIG. 1.—Survival of American roaches exposed to contact effects of various concentrations of NaF.

milligrams is apparent. Checks at hourly intervals would have been necessary in order to demonstrate positively the correlation indicated for these higher dosages.

Table 3 also shows that with one gram of NaF the roach was collecting about as much poison as the body surface could acquire, since the quantities of poison were only slightly increased when the roaches were exposed to the two gram samples.

A statistical analysis of the data of

table 3 was made. The three NaF treatment differed significantly, both as to dosage and rapidity of kill. The variation in the milligrams of NaF was largely accounted for by differences in the amount of poison found on the sternites of the abdominal segments. Small amounts of NaF were present on the tarsal segments, the antennae, the mouth parts, and the distal portion of the coxae. Roaches were observed to clean the NaF from their appendages, and the antennae appeared to acquire about the same amount of dust in all three treatments. If ingestion of NaF from the appendages was a factor in the death of these roaches, it was not evident in these data, since those roaches which collected the smaller amounts of NaF per gram of body weight apparently ingested about as much NaF as did those with the larger dosages, although these latter individuals died much sooner. In this small sample no sex difference was found, but there was some evidence that the females were more resistant to poisoning, since, although they collected 6 per cent less NaF, they lived 24 per cent longer than did the male roaches.

The statistical analysis of data in table 2 is presented in table 4. There was a significant difference between sexes in that the females lived longer than the males. This difference was also evident when NaF was tested as a stomach poison It appears that the females are probably more resistant to the NaF poisoning. No adequate explanation for this can be offered at present, but this fact is probably allied with several other sex differences previously reported by the authors (Griffiths & Tauber 1940, 1942).

The analysis reveals that the ingestion of NaF which had collected on the antennae and mouth parts did not speed up the occurrence of death. In fact, those roaches whose mouth parts were unsealed actually lived longer than the other group. The figure for those insects with sealed mouth parts is a corrected one and may not be absolutely accurate, but it is based upon the available information. Therefore, since there is a correlation between the amount of NaF collected by the roach and the rate of death and since those roaches with unsealed mouth parts did not die significantly sooner than those with sealed mouth parts, it appears that NaF serves primarily as a contact rather than as a stomach poison when roaches are allowed to walk through it. This conclusion is further confirmed by the results obtained when NaF was mixed with starch paste and fed to roaches. Ingestion of the poison produced a relatively slow death rate as compared with mortality due to the contact effects of NaF.

SUMMARY AND CONCLUSIONS.—1. By feeding starch paste which contained NaF it was determined that NaF could act as a stomach poison for adults of the American roach, *Periplaneta americana* L.

Table 4.—Statistical analysis of the effects of NaF as a contact insecticide.

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
Total	119	978.1	
Within Subclasses (error)	108	283.7	2.6
Sealed and not Sealed	1	3.0	3.0
Sex	1	80.4	80.4[1]
NaF Treatments	2	515.3	257.7[1]
Discrepance	7	95.7	13.7

[1] Highly significant.

In this experiment, females lived longer than males. The average survival time after ingestion of a lethal dose is about 3.5 days.

2. Roaches were allowed to walk through NaF. There was a correlation between the amount of NaF collected on the body surface and the rapidity with which death occurred. Adult roaches with unsealed mouth parts did not die sooner than those with sealed mouth parts. Females lived longer than males. After contact with NaF, average survival of males was about 33 hours; average survival of females was about 52 hours.

3. As a result of this controlled laboratory investigation, it appears that when a roach walks through NaF, death occurs because of contact rather than from effects of stomach poison. The cleaning of appendages is of negligible importance as a contributing factor in the mortality, since death occurs from contact effects before the ingested NaF has a chance to manifest its potential lethal property. Under actual conditions of attempted control of roaches it is, of course, difficult to isolate the causative mechanism of death. However, on the basis of the reported analysis, it seems likely that the first roaches to die are those killed from effect of contact with the NaF.—4-2-43.

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The Toxicity of *Ethide* to the Firebrat and Three Species of Stored Grain Insects

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The properties of *Ethide*,[2] 1,1-dichloro-1-nitroethane, and its probable value as an insect fumigant were first reported by O'Kane & Smith (1941). Information regarding the effects of the gas on various materials and some preliminary data on its toxicity were included in the report. Only two articles containing information on the toxicity of *Ethide* have since come to the attention of the authors.[3] Farrar & Flint (1942) carried on extensive tests to determine the toxicity of twelve fumigating mixtures at several dosage levels to a number of stored grain insects in steel bins of 2000 bushels capacity. When used at the rate of 2 pounds of liquid in 1 gallon of a carrier, such as carbon tetrachloride, *Ethide* gave satisfactory control of the insects involved, although it was not as toxic as certain of the other fumigation mixtures tested. Richardson & Casanges (1942) conducted laboratory tests to determine the toxicity of a number of chemicals as fumigants to the confused flour beetle, *Tribolium confusum* Duv. They found that a concentration of approximately 9 milligrams per liter of *Ethide* was required to give a mortality of 50 per cent, and a concentration of approximately 12 milligrams per liter was required for a mortality of 95 per cent.

In this article is reported the toxicity of *Ethide* to the firebrat, *Thermobia domestica* Pack., the saw-toothed grain beetle, *Oryzaephilus surinamensis* L., the lesser grain borer, *Rhizopertha dominica* F., and the cowpea weevil, *Callosobruchus maculatus* F., as determined by laboratory fumigation tests.

PROCEDURE.—The method employed throughout the experiment was similar to the one originally described by Grayson & Swank (1941) but later modified by Jefferson & Grayson (in press). All dosages were administered by means of glass ampules, and the weights of the fumigant were determined to 0.1 of a milligram. It was necessary to break the ampules into small pieces in order to insure the rapid volatilization of the fumigant. Balloon flasks of approximately 5.5 liters were used, and were placed in a constant-temperature cabinet operating at 30°C. for the fumigation period. Other details of the procedure were as described by Jefferson & Grayson.

The insects used in the tests were reared in constant-temperature cabinets. The firebrats were reared at a temperature of approximately 37.5°C. and a relative humidity of about 70 per cent, but the other insects were reared at a temperature of approximately 29°C. and a relative humidity of about 80 per cent. The food of the firebrats consisted of oatmeal and either dried whole milk with yeast added or dried skimmed milk with yeast added. The cowpea weevils were allowed to feed on black-eyed peas. The lesser grain borers were fed on a combination of whole-wheat flour and wheat. The saw-toothed grain beetles were fed on a combination

[1] Now in military service.

[2] Proprietary material manufactured by the Commercial Solvents Corporation.

[3] As this paper goes to press the authors wish to acknowledge the work on *Ethide* by R. W. Brubaker and W. D. Reed [JOUR. ECON. ENT. **36**(2): 300–3], by C. E. Woodworth [JOUR. ECON. ENT. **36**(2): 335–6], and by H. H. Richardson [JOUR. ECON. ENT. **36**(3): 420–6] which have appeared since its acceptance for publication.

of whole-wheat flour and cracked corn.

During the exposure period the insects were placed in 2.5 by 0.75 inch cylindrical cages, made of very fine mesh screen wire. The number of insects per subsample varied with the species. In the case of the firebrat it was approximately 30; for the cowpea weevil, approximately 50 (during the early tests approximately 30 were used); for the saw-toothed grain beetle, approximately 30; and for the lesser grain borer, approximately 50. The insects used in the tests were taken from active cultures and were selected at random. Only young adult firebrats greater than 7 mm. in length were used, while adult cowpea weevils from 1 to 10 days in age and adult saw-toothed grain beetles from 1 to 14 days in age were used. In the case of the lesser grain borer difficulty was experienced in obtaining adults of known age, because of their habit of boring completely within the grains of wheat, but it is not likely that the age of any individual used in the tests exceeded 30 days. To compensate for this the number of insects per subsample and the number of tests were increased beyond the original plan.

At the end of the exposure period the insects were removed from the cages and placed in glass jars or vials containing food. The containers were placed in constant-temperature cabinets operating at the same temperatures at which the insects were reared. The final count for the determination of the number killed was made at the end of the 72-hour period following the removal of the insects from the fumigation flask. The criteria of death employed were as follows: for the firebrat and the saw-toothed grain beetle, failure to exhibit perceptible locomotion; and for the cowpea weevil and the lesser grain borer, failure to exhibit motion of any part of the body.

RESULT.—The experimental results are plotted in figures 1 and 2. The regression lines were fitted to the points by the method of least mean squares (Bliss 1935). In those cases where the number of deaths occurring in the check samples exceeded 1 or 2 per cent the net percentage mortality was determined from Abbot's formula (Abbott 1925).

At the 5-hour exposure period the concentration of *Ethide* calculated to kill 50 per cent of the firebrats was 1.33 mg. per liter. Similarly, the concentration calculated to kill 99 per cent was 2.62 mg. per liter. A chi-square value of 2.490 was obtained, as determined by the five points of highest concentration. Only a few deaths occurred in the check samples.

At the 2-hour exposure period the concentration of *Ethide* calculated to kill 50 per cent of the firebrats was 2.79 mg. per liter. Similarly, the dosage calculated to kill 99 per cent was 4.40 mg. per liter. A chi-square value of 3.998 was obtained, as determined by the five points of highest concentration. Only a few deaths occurred in the check samples.

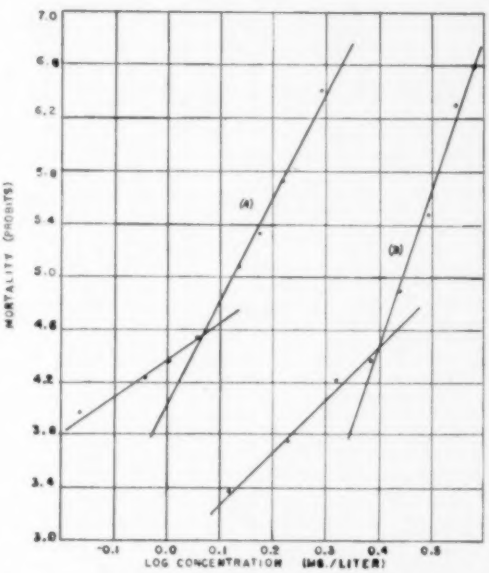

FIG. 1.—Toxicity of *Ethide* to *Thermobia domestica* at 30° C. Exposure 5 hours in (A), 2 hours in (B). The total number of insects treated for each of the points varied from 231 to 340 in (A), and from 278 to 537 in (B). In either case the regression line for the three points of lowest concentration was fitted by eye.

The concentration of *Ethide* calculated to kill 50 per cent of the saw-toothed grain beetles was 2.75 mg. per liter, while that for 99 per cent was 4.44 mg. per liter. A chi-square value of 9.590 was obtained. A mortality of 5.19 per cent occurred in the check samples.

The concentration of *Ethide* calculated to kill 50 per cent of the lesser grain borers was 2.23 mg. per liter, while that for 99 per cent was 3.88 mg. per liter. A chi-square value of 12.444 was obtained. A mortality of 4.82 per cent occurred in the check samples.

The concentration of *Ethide* calculated to kill 50 per cent of the cowpea weevils was 2.01 mg. per liter, while that for 99 per cent was 3.47 mg. per liter. A chi-square value of 22.317 was obtained. A mortality of 12.56 occurred in the check samples.

DISCUSSION.—The chi-square tests for the firebrat at both exposure periods, the saw-toothed grain beetle, and the lesser grain borer showed the observations to vary no more than would be expected from simple fluctuations in sampling. The chi-square value obtained for the cowpea weevil, however, indicated the observations to be inconsistent with the calculated dosage-mortality curve. Although the excessive fluctuation in sampling may have been due to some factor, or factors, involving the rearing and handling of the insects, the most probable explanation is the characteristic short period of longevity of the adult beetles, with the consequent high mortality in the check samples, which made it difficult to obtain consistent results. However, as pointed out by Bliss (1935), heterogeneity of this type does not necessarily invalidate the procedure of analysis employed.

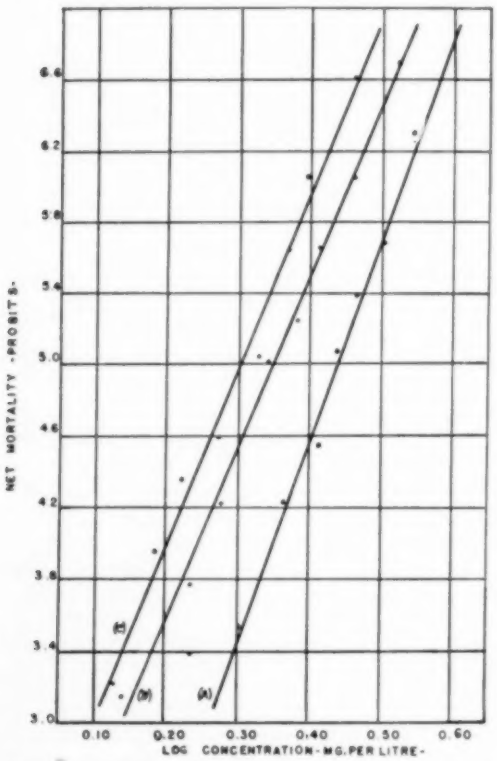

FIG. 2.—Toxicity of *Ethide* to *Oryzaephilus surinamensis* (A), *Rhizopertha dominica* (B), and *Callosobruchus maculatus* (C). Temperature 30° C.; exposure 5 hours. The total number of insects treated for each of the points varied from 258 to 525 in (A), from 450 to 738 in (B), and from 285 to 580 in (C). In (A) the point of lowest concentration was not considered in fitting the line.

Ethide was found to exhibit a delayed action which became more pronounced as the concentration was decreased. Death rarely occurred prior to removal from the fumigation flask except at the higher concentrations. The firebrats were often found to be firmly stuck to the glass surface of the container by a regurgitated fluid. No unusual action associated with death was observed with the other insects. At the concentrations employed throughout the experiment no difficulty was experienced in getting the ethide to volatilize.

Ethide was found to be as toxic, or more toxic, to the four insect species reported in this paper than to those tested by previous authors. O'Kane & Smith (1941) have reported that 8 oz. per 1000 cu. ft. (approx. 8 mg. per liter) for four hours, or 4 oz. for 8 hours, would give 100 per cent kill of the larvae of the yellow mealworm, adults of the confused flour beetle, adults of the rice weevil, and adults of the American roach. However, it should be pointed out that the dosages were based on a fumigation temperature of 26°C., and upon obtaining complete kill of all the insects. Richardson & Casanges (1942) have reported the median lethal concentration of *Ethide* to the confused flour beetle as being approximately 9 mg. per liter. The difference in resistance between these insects and those of the same species used by O'Kane & Smith might possibly be explained by the addition of yeast amd milk powder to the diet in the former case.

SUMMARY.—The results of laboratory fumigation tests with *Ethide* against the firebrat and three species of stored grain insects are reported.

At a temperature of 30°C. and an exposure period of 5 hours the concentrations of *Ethide* calculated to kill 50 and 99 per cent, respectively, of the insects were as follows: the firebrat, 1.33 and 2.62 mg. per liter; the saw-tooth grain beetle, 2.75 and 4.44 mg. per liter; the lesser grain borer, 2.23 and 3.88 mg. per liter; and the cowpea weevil, 2.01 and 3.47 mg. per

liter. Under similar conditions, except for an exposure period of 2 hours, 2.79 and 4.40 mg. per liter of *Ethide* were calculated as the dosages required to give 50 and 99 per cent kill, respectively, of the firebrat.

Ethide was found to exhibit a delayed action which was more pronounced at the lower concentrations. No difficulty was experienced in getting the material to volatilize at the concentrations employed throughout the experiment.—2-15-43.

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The Action of Bean Leaves Against the Bedbug

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It is the practice in the Balkan countries to exterminate bedbugs (*Cimex lectularius* L.) by spreading common bean leaves on the floor of infested rooms. According to Bogdandy (1927), the bedbugs crawl onto the leaves at night, and the next morning the leaves with the bugs on them are removed and burned. He states that the bugs sometimes completely cover the leaves, and that in a badly infested room he has removed 2.25 pounds of them. The bedbugs appeared to be in a dazed condition for they reacted very sluggishly upon mechanical stimulation and could hardly be induced to move from the leaves.

From this report the question naturally arises: Is there a chemical present in bean leaves which attracts and possibly dazes the bedbug? If so, it might be useful against this insect, the control of which is especially important in wartime since infestations are liable to develop in soldiers' barracks, air-raid shelters, and similar places. The action of bean leaves on the bedbug was therefore studied prior to a possible investigation of the attractant chemical, if any was found.

After preliminary studies a series of 7 tests were made, in which 24 to 273 bedbugs (average 110) were confined in an enameled pan 9 inches in diameter on which were spread 3 or 4 freshly picked bean leaves, *Phaseolus vulgaris* L. and an equal number of squares of white blotting paper of the same area as the leaves. Blotting paper is regularly used in rearing bedbugs (Woodbury *et al.*

FIG. 1.—Live adult bedbug trapped on bean leaf. Note abnormal position of legs. ×10.

[1] The writer is indebted to H. L. Haller for calling attention to Bogdandy's report, to J. G. Pratt for making the photographs, to Carlo Zeimet for helping with the translations, and to S. F. Blake for suggesting types of plants.

1939, Campbell *et al.* 1941), and once placed on it the insect rarely leaves except to feed. The pan was covered loosely with a similar pan to keep out light, and the insects were allowed to remain overnight. Upon examination the next morning on an average 32 per cent of the bedbugs (ranging from 12 to 62 per cent) were found on the bean leaves; the remainder had gathered on the under side of the blotting paper. Other types of foliage were also tested, but they gave negative results.

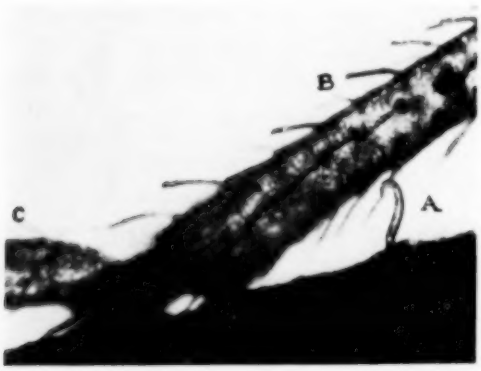

FIG. 2.—*A*, Hooked hair present on bean leaf; *B*, tibia of bedbug leg; *C*, tarsal segments of bedbug leg. ×200.

This rough test at first seemed to indicate that bean leaves might have some attractant powers, but on closer observation it appeared that the bedbugs were trapped in some way on the leaf. Figure 1 shows that the legs of the bedbug caught on the leaf are stretched out in an abnormal position. Most bedbugs at rest tuck the lower parts (tibia, tarsi, and claws) of the second and third pairs of legs under or alongside the abdomen. Under higher magnification, as shown in figure 2, the bean leaves were found to have small hairs, with a sharply pointed hook at the distal end, on both the upper and the lower surface of the leaves. Usually the tarsal segments or the claws of the insect's leg are caught by the hooks, and in some cases the sharp point of the hook appeared to be embedded in the outer covering (cuticle). The hooks are strong, and when a leg is caught the insect usually struggles vigorously so that other legs become entangled.

Bogdandy states that the bean leaves should be placed with the under side up. In the present tests the majority of the insects were caught on the under surface, and examination revealed more hooked hairs on this side.

Apparently the bedbug walks up onto the bean leaf simply by chance and walks off it just as casually unless a leg becomes entangled in the hooks. There appears to be no attractant action.

The fact that some bedbugs remained on the exposed surface of the leaf, rather than hidden underneath, where they would normally be found, is another indication of a restraining, trapping effect. Kemper (1936) stated that Bogdandy was mistaken in his observation that bean leaves have an attractive action. Kemper believed that the presence of numerous bedbugs on bean leaves may be explained simply by their habit of seeking a protected place. However, the present results do not support that explanation, since the bedbug would normally seek protection on an unexposed surface.

This trapping action will also explain, but not support, Bogdandy's statement that the insect appeared dazed and could hardly be induced to move. According to further observations, the insect, once caught, rarely frees itself, except by molting, and the cast skin remains caught in the hooks. There seemed to be no dazing effect, for after bring freed of the hooks the insects moved off rapidly and appeared quite normal. The fact that trapped insects remained alive for some time and finally starved to death also indicates the absence of any toxic effect.

Once several insects were caught on a leaf, others came and rested among those that were trapped. This was apparently due to the herding, or grouping, habit of the bedbug.

Only two varieties of bean leaves were tested, Early Bountiful variety of bush beans and an undetermined variety of kidney beans. In future tests it may be desirable to try a wide selection for possible differences in efficiency.

Tests were also made with a number of other types of plant foliage, including alfalfa, coleus, chrysanthemum, fuchsia, and white clover, but the results were negative. None of these plants had the hooked hairs.[1]

[1] These hooked hairs on beans have been observed by Poos and Smith (1931) to have an adverse effect on the young nymphs of *Empoasca fabae* (Harr.). They report that the young nymphs were frequently impaled on the hooks of bean (Stringless Greenpod). They did not observe this action with some other host plants, none of which had hooked hairs.

Tests were also made with the seed pod of the common weed tick trefoil, or beggar's-lice (*Desmodium* sp.), which is covered with small hooked appendages similar to but larger than those on bean foliage. The bedbug can also be trapped on the hooks of this plant (Fig. 3).

The practicability of the use of bean leaves in bedbug control has not been tested. Bogdandy states that all the bedbugs were destroyed after three or four renewals of the bean leaves. It seems probable that large populations of bedbugs can be greatly reduced in this way, and the method may be worth a trial where no suitable insecticides are available. However, there would be no effect on the eggs, and complete extermination by this method seems very questionable.

SUMMARY.—To find out why bean leaves are used in the Balkan countries for trapping bedbugs (*Cimex lectularius* L.), bedbugs were confined with bean leaves overnight in the laboratory. The results indicate that bean leaves have no attractant action, but they do act as traps by means of the small hooked hairs present on both sides of the leaves. The legs of the insect become entangled in these hooks. The seed pod of the common weed tick trefoil exerts a similar action. Other types of foliage that had no hooked hairs gave negative results.—2-22-42.

FIG. 3.—Bedbugs trapped in hooks on seed pod of tick trefoil. Note cast skins left by bedbug in freeing itself from the hooks.

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Lures Attractive to the Apple Maggot[1]

A. C. HODSON, *University of Minnesota, St. Paul*[2]

The studies of McPhail (1939) on protein lures attractive to flies in the genus *Anastrepha* have stimulated a lively interest in the use of baits as attractants for other trypetid flies. Dean (1941) reported on the efficiency of a number of decomposing protein lures which were used to attract the apple maggot, *Rhagoletis pomonella* Walsh. Boyce & Bartlett (1941) applied some of McPhail's results in trapping experiments with the walnut husk fly *Rhagoletis completa* Cress. The particularly encouraging results of the walnut husk fly investigation prompted a test in Minnesota of the most promising materials as lures for the apple maggot. A preliminary study was completed in 1941, Benjamin and Hodson (1942), in which several decomposing protein baits, including the so-called McPhail bait, were found to be much inferior to the glycine-sodium hydroxide bait used by Boyce & Bartlett.

[1] Paper No. 2074 Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul, Minn.

[2] This investigation was carried on in cooperation with A. G. Ruggles, State Entomologist of the State Department of Agriculture, Dairy and Food. Merle W. Wing, of the State Entomologist's Office, conducted most of the field work.

During the 1942 fly season glycine was tested further and several other chemicals compared with it.

A total of 9039 flies were caught during the season by 214 traps placed in 125 trees. Only eight trees were protected with traps throughout the entire season, most of the flies being caught during test periods lasting 10 days or less. Five pound honey pails were used as traps in most of the experiments and one-quart oil cans were given more limited use. The glass, Mediterranean fruit fly, trap was much inferior to open traps of all designs. Glycine was used at the rate of 1 per cent in a 1 per cent sodium hydroxide solution.

The 1941 experiments indicated that the glycine bait would remain attractive for several weeks, even after most of the water had evaporated and the pails were replenished. Because of the practical significance of this observation and a similar report by Boyce & Barlett an experiment was designed to compare baits different only in age in which five traps were hung in the orchard for two, four and six weeks before being tested. The lures were compared directly with one of each being hung in each of five trees. A total of 939 flies were caught in 10 days and 700 of them were trapped in the oldest preparation. The superiority of this lure persisted throughout the 10-day period and was nearly equally great in all five trees. There was no significant difference in the catch of the 2 and 4 week series, there being 118 and 121 flies caught respectively. Fresh material in traps nearby attracted slightly fewer flies than the two and four week old baits but the comparison was not complete because there was no direct competition.

A review of the extensive Italian, South African and Australian literature describing the use of lures for the attraction of several species of trypetids, infesting especially citrus fruits and olives, made it evident that all the lures recommended had one important constituent in common with protein and glycine lures. All of them contain ammonia and release it upon decomposition. Consequently ammonia baits were compared with fresh glycine in a series of exploratory experiments. In the first attempt 1 and 2 per cent household ammonia and 1 per cent ammonium sulphate were tried. Six one-quart oil cans were used for each material and trapping was carried on for seven days with an arrangement in which pairs of traps were placed one on each side of a tree. This preliminary test was encouraging because 145 flies out of a total of 375 were caught by the 1 per cent household ammonia. The 2 per cent household ammonia and 1 per cent ammonium sulphate caught 73 and 93 respectively. Fresh glycine came in fourth place with 64 flies. Even though the catches were light because of the use of the less efficient oil cans and unfavorable weather both household ammonia and ammonium sulphate were significantly superior to fresh glycine.

About this time several traps were observed closely in order to determine just how the flies became engulfed. In a number of instances they flew directly into the liquid from the lip of a honey pail and in too many cases they were able to escape after sculling about on the surface. It seemed obvious that the addition of some material to lower the surface tension and thereby wet the flies more quickly would prevent many from escaping. In a preliminary test with glycine nearly twice as many flies were caught when 0.1 per cent granulated soap was added. The bait was much easier to handle and just as efficient when *Dreft* was used instead of soap which gelled quickly in a sodium hydroxide solution. Following these discoveries another test of ammonia lures was made in which the addition of soap produced astonishing results.

The standard glycine bait (A) was compared with a 1 per cent solution of household ammonia, with and without soap (B and C), 1 per cent ammonium sulphate (D), and the glycine bait with granulated soap added (E). Six traps were used for each material and rotated among 15 trees so that each material was compared directly with each of the others. The results are shown in table 1. The number of flies caught is designated under letters which refer to the materials mentioned above and on the dates indicated.

Table 1.—The effect of the addition of soap on the efficiency of lures.

DATE	A	B	C	D	E
8/21/43	83	432	57	138	94
8/25/43	37	727	30	319	112
8/28/43	20	226	14	66	23
Total	140	1385	101	523	229

The ammonia-producing solutions, household ammonia and ammonium sulphate again appeared highly efficient as compared with fresh glycine. Regardless of the combination of traps in any one tree 1 per cent household ammonia caught several times as many flies as any other lure. Subsequent tests continued to show a very high degree of attractiveness when this solution was used. The addition of soap to the household ammonia solution not only prevented flies from escaping easily, but prevented ammonia from being liberated too rapidly. The latter was evidenced by an odor of ammonia above the soap solution after none could be detected when household ammonia was used alone. Laboratory tests have since substantiated this conclusion. At the completion of this experiment there was too little time left to be able to determine how long the household ammonia and soap solution would be attractive, but a few additional tests indicated that it could be used effectively for as long as 2 weeks.

Other experiments in which household ammonia was compared with ammonium sulphate and ammonium acetate in a soap solution indicated that the addition of soap reduced the great advantage which household ammonia held otherwise. When granulated soap and *Dreft* were compared there was no significant difference in the catch no matter which attractant was used.

The very important question regarding the use of lures in traps as a means of control of the apple maggot was not answered directly by trapping an entire block throughout the fly season, however, some indirect evidence of trap efficiency was obtained. A honey pail trap was hung in each of eight trees when the first flies were observed. Each week thereafter for 5 successive weeks eight neighboring untrapped trees were selected and traps placed in them. All the traps were allowed to remain in their initial positions from the time when they were first hung, until the end of the experiment, resulting in 48 traps in service at the beginning of the final 2 weeks. Glycine was used as the attractant and was changed once each week in all traps at the time when a new set was hung. Flies were removed and counted at semiweekly intervals but for convenience the numbers are presented as weekly catches in table 2.

Traps which were set up the first 3 weeks caught more flies each week as the season progressed because the peak of emergence did not occur until about the middle of August. After the third week catches counted during the first week of trap operation were consistently greater than those in the following weeks; thus indicating that flies had accumulated in the absence of traps and were materially reduced in numbers by the subsequent trapping. That the lower catches observed after the first week were due to the action of traps is demonstrated further by the fact that the number of flies caught when each lot of traps was operating for the first time was always much greater than the coincidental catches found in older traps. The immediate reduction in population size is even more striking than shown in table 2, because 612 of the 901 flies caught by the fifth lot of traps during their first week was captured during the first 3 days. Likewise 436 of the 719 caught by the sixth lot were taken during the first 3 days. The very high catch shown in the fifth column is due probably to the location of those trees nearest a part of the orchard most heavily infested during 1941. Some indication of the possibility of control by trapping was demonstrated by a reduction of the number of maggots per apple in trees trapped throughout the season to a little less than one-third of the number found in apples from check trees. This reduction took place in spite of the fact that the trees were surrounded by others which were trapped for only a few weeks or not at all.

Table 2.—The number of flies caught over a seven week period by groups of eight traps set out at weekly intervals.

DATES	LOT 1	LOT 2	LOT 3	LOT 4	LOT 5	LOT 6
7/21–7/28	*17*					
7/28–8/4	30	*165*				
8/4–8/11	59	40	*97*			
8/11–8/18	61	64	108	*304*		
8/18–8/25	93	99	79	111	*901*	
8/25–9/2	208	171	152	188	236	*719*
9/2–9/8	27	33	17	23	35	56
Total	495	572	453	626	1172	775

Trapping gave an excellent picture of the progress of fly emergence and provides a means of obtaining information which can be used in timing spray applications. This method is probably as reliable as the

use of ground cages over soil containing puparia even though the sex ratio as indicated by trap catches is somewhat different from emergence records obtained in cages. Out of 8975 flies which were sexed in several trapping experiments 6185 or 68.6 per cent were females. The usual proportion of females as determined by counts made in emergence cages generally is found to be about 60 per cent. There is evidently little lag between emergence and the time when flies appear in traps because a high percentage of those caught during the season were less than 15 hours old. Young flies can be recognized easily because the conspicuous white spot on the scutellum appears to be divided until 10 to 15 hours after emergence. Of the 8975 flies examined for age and sex 52.9 per cent of the females and 50.4 per cent of the males had the white spot divided. Many of the young flies were drowned in traps when the ptilinum was still protruding from the head and before the intestinal contents had been evacuated. When one considers the relatively long preoviposition period of this species the high proportion of very young flies attracted by lures has added significance.

Some other characteristics of ammonia lures are of interest, one of the most surprising of which is the very small number of individuals of other species attracted. Only an occasional trap baited with glycine caught anything besides the apple maggot (with the exception of a few codling moth adults). Household ammonia and ammonium sulphate also attracted very few other species, most of them small Diptera. One of the serious faults charged against trapping in general is that insects are drawn into an area by chemical lures or lights in much greater numbers than would be present naturally, and then only a small number is caught or oviposition may take place before capture. Two lines of evidence suggest that this disadvantage is not characteristic of lures used in this investigation. In the first place very few flies were caught in traps hung in nonbearing trees while many were caught in adjacent trees bearing fruit. The second observation was made in the course of the study of trap efficiency. After the population in one group of trees was reduced by trapping there was a high catch in trees in an adjacent row a week or more later which indicated that flies were not drawn to traps from great distances. Late in the season flies concentrated in the few trees bearing late varieties, which would make it seem even more likely that fruit provides the principal attraction and the chemical lures operate in a more restricted manner.

Laboratory studies are underway at present in which the most attractive lures are being tested to determine the manner in which ammonia is produced and released. Of the new materials being investigated urea is one of the most promising because of the low cost and the fact that it has a high ammonia content and releases ammonia slowly in an alkaline solution. Further experimentation with this and other untried materials is anticipated for the 1943 season.

SUMMARY.—One per cent glycine in a sodium hydroxide solution became more attractive to the apple maggot flies after being exposed in the orchard for several weeks. The addition of soap to the glycine lure and other chemicals increased their efficiency to a marked degree. Household ammonia, ammonium sulphate and ammonium acetate all were superior to the fresh glycine lure. Tests of trap efficiency indicated the possibility of using this method as an important supplemental control measure.—3-12-43.

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Sorption of Methyl Bromide by Soil in a Fumigation Chamber

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One of the treatments authorized by the United States Department of Agriculture (B.E.P.Q. 499 and Supplement 1) for eradicating the Japanese beetle in plant material, both with and without soil, consists of fumigation with methyl bromide. The administrative instructions specify the dosages to be used for exposures at different temperatures, but in all cases the space occupied by the load is included in each 1000 cubic feet.

In fumigations under field conditions the size of the load in the fumigation chamber and the type of soil and its moisture content are not constant. Consequently, an investigation was made to ascertain the effect of these variables upon the amount of methyl bromide in the atmosphere of a fumigation chamber throughout the treatment period, and upon the weight of methyl bromide sorbed by the soil.

The general plan of study consisted in determining the concentration of the gas at intervals during 6 hours after the chamber was charged with methyl bromide at the rate of about 2 pounds per 1000 cubic feet, (1) when the chamber was empty and dry, (2) when the chamber contained more than enough moisture to saturate its atmosphere, and (3) when the chamber contained an amount of one of three soils, of different properties, greater than would be normally encountered in fumigations; and in calculating the difference in concentration during the 6-hour period between the empty and the loaded chamber and the weight of methyl bromide sorbed by the soils.

Equipment.—The fumigation chamber was a 50-cubic-foot insulated metal-lined box, 7 feet 8 inches long, 2 feet 4 inches wide, and 2 feet 20 inches high. The top was removable and was bolted in place when the chamber was in use. A rubber gasket formed a gastight joint between the top and the body of the chamber. The heating apparatus, which was located near one end of the chamber and below an evaporating pan, consisted of two 200-watt electric lights connected in series with a thermostat. Circulation was accomplished by means of a 12-inch fan located in back of the heating unit. The chamber was also equipped with three horizontal racks with a space equal to about one-third of the height of the chamber between them, the bottom rack being slightly above the floor. The volume of the voids in the chamber containing all this equipment was calculated to be 46.5 cubic feet.

Openings in the top of the chamber were provided for a tube through which the methyl bromide was introduced, for two gas-sampling tubes, and for a thermometer.

The fumigation chamber was located and operated indoors to minimize the effect of outside weather conditions.

Soils.—The three soils selected for study were widely different in chemical and physical properties, and only a general attempt was made to classify them as to type. One of the soils consisted largely of sand, the second was chiefly clay, and the third was a peat produced in Michigan.

Normal Rate of Decrease in Empty Dry Chamber.—Late in the afternoon the chamber was closed, the fan started, and the heating unit turned on to precondition the chamber at a constant temperature of 75°F. during the night. On the following morning 45 grams of methyl bromide (equivalent to 2 pounds per 1000 cubic feet of box space) was weighed in a closed metal cylinder. The cylinder was immersed in hot water and the methyl bromide discharged into the vaporizing pan. After 20 minutes two 1-liter samples of the atmosphere of the chamber were drawn simultaneously through the sampling tubes from a point 2 inches below the center of the chamber lid and analyzed by an adaptation of the method described by Stenger *et al.* (1939). Other samples were taken after 1, 2, 4, and 6 hours.

Since the volume of the voids in the empty fumigation chamber was only 46.5 cubic feet, the initial concentration of methyl bromide in the air was actually 2.13 pounds per 1,000 cubic feet. After

[1] Much of the equipment and materials used in this investigation was furnished through the cooperation of various divisions of the Bureau.

6 hours the average concentration of closely agreeing duplicates was 1.80 pounds per 1000 cubic feet. The rate of decrease was uniform throughout the 6-hour period and amounted to almost 2.5 per cent per hour.

EFFECT OF EXCESS MOISTURE.—Fifty pans 8 by 3 by 1.25 inches containing water were distributed on the racks in the chamber. In one test each pan contained 100 ml. of water, and in a second test each contained 250 ml., but since there were no significant differences, the results have been averaged. The fumigation procedure previously described was followed.

Table 1.—Methyl bromide concentrations in a chamber loaded with various soils relative to the concentration in the empty chamber.

Load	Relative Concentration (Empty Chamber = 1.00)					
	Initial	After 20 minutes	After 1 hour	After 2 hours	After 4 hours	After 6 hours
Sand						
Wet	1.13	1.08	1.05	1.01	1.01	1.03
Dry	1.12	1.05	1.03	1.00	1.02	1.02
Clay						
Wet	1.14	1.09	1.04	1.00	0.97	0.96
Dry	1.10	0.93	0.84	0.81	0.82	0.83
Peat						
Wet	1.13	1.06	1.01	0.92	0.84	0.84
Dry	1.08	0.82	0.68	0.61	0.61	0.59

The inside surfaces of the chamber after the overnight preconditioning period were covered with condensed water vapor. The initial concentration of methyl bromide was 2.14 pounds per 1000 cubic feet, being substantially the same as that in the empty chamber. The average concentration after 6 hours was 1.78 pounds per 1000 cubic feet. Since the concentration therefore decreased at about the same rate as in the empty chamber, moisture is not an important factor in modifying the concentration of methyl bromide in the atmosphere of fumigation chambers.

EFFECT OF SOILS IN THE FUMIGATION CHAMBER.—The soils were firmly packed into 96 ordinary 6-inch flowerpots, which were sufficient to load the three racks in the chamber. Two tests were conducted with each soil in an air-dried condition and two after the soil had been thoroughly wet and further compacted in the pots. After each test the soil was thoroughly aerated by spreading it in a thin layer in the open and then repacking it into the pots, and the inside of the fumigation chamber was sponged with water and dried. The fumigation procedure previously described was followed. The results of duplicate analyses corresponded closely.

The actual volume of the soil used in each test was calculated by determining the volume of water displaced by the soil in each of three pots selected at random and multiplying the average volume by the number of pots in the load (96). The volume of the pots was determined in a like manner.

The amount of moisture in the loads was determined by air-drying samples of each soil obtained by taking three 1-inch cores from each of three pots.

The relative concentrations of methyl bromide in the loaded chamber as compared with the concentrations in the empty chamber are presented in table 1.

The initial concentrations of methyl bromide were higher in the loaded chamber, and during the first part of the 6-hour period the concentration decreased faster in this chamber. In the chamber loaded with either wet or dry sand the rate of decrease during the last 4 hours was substantially the same as in the empty chamber and the concentration was slightly greater. The concentration in the chamber loaded with wet clay became equal to that in the empty chamber in 2 hours, but in the chamber containing dry clay only 15 minutes was required. With the wet-clay load the concentration decreased more rapidly than in the empty chamber during the remainder of the 6-hour period, while with the dry-clad load this difference reached a maximum in about 2 hours and then decreased slightly. In the chamber loaded with wet peat the concentration became equal to that in the empty chamber in 1 hour as compared with about 5 minutes for the dry-peat load. With the wet-peat load the concentration decreased more rapidly than in the empty chamber during most of the remainder of the 6-hour period, while with the dry-peat load this difference reached a maximum in about 2 hours and then remained constant.

WEIGHT OF METHYL BROMIDE SORBED BY THE SOILS.—The weight of methyl bromide sorbed by the soil was considered to be the difference between the weight of the charge (45 grams) and the sum of the weight in the atmosphere of the chamber plus the weight lost by leakage. In calcu-

lating weight lost by leakage it was assumed that the same uniform absolute rate of loss occurred as in the empty chamber, namely, 25 grams per 1000 cubic feet per hour. It would be expected that the rate of loss would be larger than this while the concentration in the loaded chamber was greater than that in the empty chamber, and vice versa. The values obtained from these calculations, as previously explained, are probably a little too large for the early part of the 6-hour period and a little too small for the latter part. Consequently, the curves drawn from these calculated values, and presented in figure 1, should be considered as located only approximately.

CONCLUSION.—Since the results of this investigation demonstrate that the concentration of methyl bromide in the atmosphere of the chamber during fumigations is influenced by the type of soil and its moisture content, it is expected that the effect of methyl bromide fumigation on certain plants may be influenced by these factors. Also, since the weight of methyl bromide sorbed by the soil is influenced by the same factors, the insecticidal value of methyl bromide against insects in soil may likewise be variable.

Although no attempt was made to determine the rate at which methyl bromide escapes from different soils after a fumigation, it is suggested that this factor may also be influenced by the type of soil and its moisture content. If such is the case, the postfumigation effect also may be variable.

SUMMARY.—An investigation was conducted to determine the influence, during fumigations, of excess moisture and type of soil upon the concentration of methyl bromide in the atmosphere of the chamber and upon the weight of methyl bromide sorbed by the soil. It was found that the rate of decrease in an empty chamber containing an excess of moisture was substantially the same as in an empty dry chamber. Three soils—sand, clay, and peat—were exposed in a chamber charged with methyl bromide at the rate of approximately 2 pounds per 1000 cubic feet. After 6 hours the concentration in the chamber loaded with dry soils was 102, 83, and 59 per cent, respectively, of the concentration in the empty chamber. With wet-soil loads the concentrations were higher in each case. Dry peat sorbed a maximum of 41 per cent of the charge or about 4½ times as much as sand, and dry clay sorbed 25 per cent or 2 ¾ times as much as sand. Dry soils sorbed more methyl bromide than wet soils. It is suggested that consideration should be given to the influence of these factors on the effect of methyl bromide on plants and its insecticidal value during fumigation and postfumigation periods.—3-10-43.

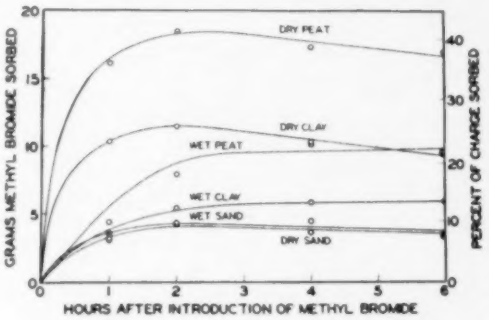

FIG. 1.—Methyl bromide sorbed by various wet and dry soils during 6 hours in the fumigation chamber.

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DR. E. A. MCGREGOR RETIRES FROM THE BUREAU

Dr. E. A. McGregor of Whittier, California has reached the retirement age and his retirement from the Bureau of Entomology and Plant Quarantine became effective on April 8, 1943. He began his service in the Bureau in 1910.

Dr. McGregor has recently completed a long-time study on the control of the citrus thrips. He is also well known as an authority on the spider-mites, especially those injurious to vegetation and has consented to serve as a collaborator in the Bureau in studies, especially in identification, of these and related pests.

Dr. McGregor may still be addressed at Whittier, California, Box 70.

Effect of Fumigation with Methyl Bromide and Paradichlorobenzene on Germination and Productivity of Seed Sweetpotatoes

STEPHEN S. EASTER and GRIFFIN L. PHILLIPS,[1] *U. S. Department of Agriculture, Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Experimental work on the fumigation of sweetpotatoes has been conducted for several years at Sunset, La., by the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture in cooperation with the Louisiana Department of Agriculture and Immigration. One of the primary purposes of this work has been to develop a method of freeing the seed sweetpotatoes of all living stages of the sweetpotato weevil, *Cylas formicarius elegantulus* (Summers), an insect which completes its life cycle from egg to adult within the potato roots. The greatest degree of success was obtained by the use of methyl bromide (Easter 1940), but it was found necessary to fumigate and hold the potatoes for several days after treatment at a temperature of at least 70° F. This is not a normal temperature at Sunset in February or March. To determine the effect of heating alone, as well as heating and fumigation, a series of experiments with replicated seed beds were carried out in 1939 and 1940.

Whereas the work on fumigants did not include tests of paradichlorobenzene, information on the comparative effectiveness of this fumigant was considered desirable inasmuch as it was suggested and used in the treatment of seed stock. Cockerham & Deen (1936) had conducted a limited number of experiments with this fumigant at Biloxi, Miss., and suggested treatment with 1 ounce of the fumigant per crate of sweetpotatoes for 21 days in barrels or other tight containers. They concluded that paradichlorobenzene retarded production of early draws, but that the total production throughout the season was not reduced. The farmers in the Sunset area who tried the treatment appeared generally to object to the long fumigation period and the retarding of the production of early draws. They considered early high production of draws of greatest importance. The suggested treatment and two modifications of it were included in the replicated seed beds in 1939 and 1940.

The seed sweetpotatoes were planted according to general practice, under about 2 inches of soil and in raised beds to provide for drainage. In 1939, 50 pounds (one crate) of potatoes were used per bed. In 1940 only 42 pounds were used per bed and the results were calculated to a 50-pound basis. In 1939 the seed sweetpotatoes were selected just before treatment from a large stock pile of below-average quality. In 1940 excellent potatoes were used, having been selected in the fall of 1939 and carefully stored until used. The sweetpotatoes used in all treatments were obtained from storage, and all were bedded the same day. Roots infested with sweetpotato weevils were included in all treatments.

To eliminate from the experimental comparisons possible differences in fertility which may exist between whole rows or whole columns of plots, the experimental area was divided into 49 plots, 7 to a row. Since 7 treatments were to be compared, the potatoes subjected to a treatment were divided into 7 lots, and following a latin-square design plantings were so randomized that a treatment was represented once in each row and once in each column. The treatments were as follows:

1. Bedding directly after storage according to general practice (check).
2. Holding at 70° F. for 8 or 9 days and then bedding.
3. Fumigation in soil-covered tight barrels with 1 ounce of paradichlorobenzene per crate for about 21 days at 50° F. or less and 60° and then holding for 8 days at 70° before bedding.
4. Same as treatment 3 except that the heat treatment was replaced by immersion of the sweetpotatoes in water for 48 hours in 1939 and 24 hours in 1940 before bedding.
5. Same as treatment 3 except that the sweetpotatoes were bedded directly from the barrels. This is the treat-

[1] Baker J. Guilbeau and Gaston Horaist, Jr., assisted in the work.

ment suggested by Cockerham (1937).

6. Fumigation with methyl bromide at the rate of 45 ounces per 1000 cubic feet for 4 hours at 70° F. and holding for 8 or 9 days in storage at 70° before bedding.
7. Fumigation with methyl bromide at the rate of 55 ounces per 1000 cubic feet for 5 hours at 70° F. and holding for 8 or 9 days in storage at 70° before bedding.

Weevil mortalities following treatments 3, 4, 5, 6, and 7 are shown in table 1. Mortality was determined from counts of adults, larvae, and pupae taken from the roots 10 days or more after treatment. Any insects capable of movement at this time were counted as surviving. They were not held for further observation. Such data were not obtained for treatments 1 and 2, since previous work had shown that the natural death rate is very low in the stages used. All first instars were disregarded in the counts, as they are easily killed by light dosages of methyl bromide. Larval mortality was determined almost exclusively on the last instar, which is the most difficult to kill.

All commercial draws were pulled from all beds three times each season. Where possible the plants from all beds were pulled on the same day, and in no case did the operation extend more than 2 days. Men familiar with the local planting of sweetpotatoes pulled and graded the plants. The early production of draws is of first importance, as no heated beds are used in the Sunset area, the custom being to bed sufficient seed to produce an abun-

Table 1.—Mortality of adults, larvae, and pupae of the sweetpotato weevil in seed sweetpotatoes following fumigation with methyl bromide and paradichlorobenzene.

Treatment	Fumigation Period	Number of Adults	Per Cent Mortality	Number of Larvae	Per Cent Mortality	Number of Pupae	Per Cent Mortality
Paradichlorobenzene:	*1939 (fumigation at 50° F. or less)*						
(3) Plus heat	Jan. 26–Feb. 14	348	100.0	764	73.7	107	100.0
(4) Plus water	Jan. 31–Feb. 21	54	100.0	131	87.8	99	100.0
(5) Alone	Feb. 2–23	70	100.0	105	95.2	47	100.0
	1940 (fumigation at 60° F.)						
(3) Plus heat	Jan. 29–Feb. 20	62	96.8	10	100.0	27	100.0
(4) Plus water	Feb. 6–27	48	97.9	4	100.0	1	100.0
(5) Alone	Feb. 7–28	46	100.0	18	55.5	15	93.3
Methyl Bromide:	*1939 (fumigation at 70° F.)*						
(6) 45 ounces	Feb. 15	156	100.0	213	86.8	69	85.5
	Feb. 8	299	100.0	215	100.0	72	100.0
	Feb. 15	73	100.0	210	100.0	13	100.0
	Mar. 4	23	100.0	3	100.0	28	100.0
(7) 55 ounces	Mar. 4	115	100.0	5	100.0	42	100.0
	Nov. 6	1,279	100.0	3,850	100.0	2,063	100.0
	Nov. 16	539	100.0	1,156	100.0	920	100.0
	Nov. 30	113	100.0	819	100.0	279	100.0

Table 2.—Production of sweetpotato draws from seed stock given the various treatments.

Treatment	Number of Draws per Plot						First, Second, and Third Pullings
	First Pulling			First and Second Pullings			
	1939	1940	Combined	1939	1940	Combined	
(1) Check	4,548	1,828	6,376	9,130	5,621	14,751	20,641
(2) Heat	4,442	3,556	7,998	9,109	6,016	15,125	21,085
(3) Paradichlorobenzene and heat	3,449	706	4,155	8,182	5,420	13,602	19,615
(4) Paradichlorobenzene and water	104	891	995	482	3,509	3,991	6,278
(5) Paradichlorobenzene	1,752	912	2,664	6,361	5,588	11,949	17,510
(6) Methyl bromide 45 ounces	4,349	3,829	8,178	9,038	6,479	15,517	21,462
(7) Methyl bromide 55 ounces	3,087	3,744	6,831	6,194	6,174	12,368	17,398

dance of late draws or vine cuttings. The weather conditions during the seasons of 1939 and 1940 were not similar. In 1939 there was little rain, draw production was delayed and reduced, and a heavy frost early in April destroyed all early draws. In 1940 there was ample rainfall, and damage from late frost was averted by covering the beds.

A consideration of treatments 1 and 5 is important as these are the check and the suggested treatment with paradichlorobenzene. More draws were taken from the check plots in every case. Although more draws were obtained from plots in which the seed sweetpotatoes had received a light treatment of methyl bromide than from the check plots, the increases were not large. When comparisons were made, however, with the draws from the plots treated with paradichlorobenzene, six of the seven increases were large. Treatment 7 gave about the same production as the check in the first pulling for 1939–40 but considerably less in all other pullings except the first for 1939. This treatment gave a complete mortality of weevils. The use of heat did not give consistent increases. The use of water after treatment was worthless.

SUMMARY.—Commercial seed sweetpotatoes were fumigated with paradichlorobenzene and methyl bromide and bedded according to standard farm practices. The commercial draws were pulled and counted three times each season in 1939 and 1940. Seven treatments were used each year with seven plots of each arranged in a latin square. Paradichlorobenzene did not give complete weevil mortality and retarded germination of the sweetpotatoes. A light dosage of methyl bromide followed by heating gave incomplete mortality and small increases in draw production. A heavy methyl bromide treatment, which gave complete mortality, did not affect the production of draws in the first pulling. In 1940, when carefully selected seed stock was used, the production of draws was not affected through three pullings.—10-8-42.

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Practical Field Tests of Oils and Oils Containing Other Insecticides for the Control of the Earworm in Southern California

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In connection with investigations of the tomato fruitworm, *Heliothis armigera* (Hbn.), on tomato in southern California, an opportunity was afforded for testing the efficiency of various oils, used alone and in combination with pyrethrins and dichloroethyl ether, in combating this insect on sweet corn. This method of control has been developed by Barber (1938, 1939, 1940, 1941) and by Pepper & Barber (1940).

A preliminary test by a grower at Garden Grove, Calif., in 1939 using oil as recommended by Barber (1938, 1939a) gave promising results. Encouraged by these findings and by the discovery during that season by Barber (1939b) that the effectiveness of the treatment was increased by the addition of 1 per cent of pyrethrins to the oil, the grower made plans to use the treatment more extensively in 1940. Other growers became interested, and as a result about 100 acres at Garden Grove were treated in 1940 and a larger acreage at Garden Grove and Indio in 1941. Several growers cooperated in making replicated comparisons of various treatments, the results of which are presented in this paper. The growers supplied the materials and timed and made the applications, and the

[1] L. J. McIntosh assisted in these studies in 1939 and 1940, M. M. Barnes in 1940 and 1941, and A. F. Howland in 1941. The growers in whose fields the tests were conducted were William Beers, Garden Grove, and Robert Bowlin, Indio.

writer and his associates assisted in laying out the fields and in checking the results.

Methods.—The insecticides were applied by laborers using pistol-grip oilers regulated to deliver 0.75 ml. of oil per stroke. The oilers were connected by a hose to a 1- or 2-gallon can carried on the back of the operator on a pack rack so that the oil was fed to the oiler by gravity. The pack rack held the supply can high enough to permit a continuous flow of oil to the oiler, and the flow was regulated by a pressure clamp (Fig. 1).

The insecticide treatments and usually the check treatment were replicated in each field 4 to 9 times in a randomized-block arrangement. Each plot consisted of 2 to 4 rows of Golden Cross Bantam sweet corn. The plots ranged in length from 260 to 600 feet, depending on the field. Fifty or more ears in each plot were examined for earworm injury, and the relative efficiency of the treatments was judged by the percentages of ears that were free of such injury. In most of the tests the average length of the area of undeveloped kernels at the tip of 25 ears in each plot was measured and used as an index of injury by the insecticide.

The ears received only one application, but not all were treated at any one time. In 1940 at Garden Grove the first application was made when about 60 per cent of the ears were pollinized and the second after a 4- or 5-day interval. The ears treated the first time were marked with a lumber crayon so that they could easily be detected and skipped the second time. In 1941 at Indio the same method was used except that the ears were not marked and on the second trip through the field the operators decided whether an ear had been treated previously. In 1941 at Garden Grove the first application was made when about 40 per cent of the ears were pollinized, and the fields were gone over a second and third time at 3- or 4-day intervals.

The following method of marking the ears, developed in 1941 by J. W. Sallee, of Aguanga, was also used and appeared to have considerable merit. A small can containing a pad saturated with thin paint was carried on the operator's belt. The operator moistened his thumb and forefinger with the paint (about every six ears) and left a mark on the ear as he took hold of it to steady it for injecting the oil with the other hand.

Insecticides.—The materials used in 1940 were a clear U. S. P. mineral oil with a viscosity of 185,[2] both with and without 0.2 per cent of pyrethrins as oleoresin of pyrethrum, and a commercial mixture stated by the manufacturer to contain 0.2 per cent of pyrethrins as oleoresin of pyrethrum in an oil having a viscosity of 100 and containing 99 per cent of unsulfonated residue.

FIG. 1.—Pack-rack gravity oiler. Vent in cap is of ¼-inch copper tubing and outlet at bottom is of ¼-inch copper tubing. Inside of can opening at top is covered with a brass screen to prevent debris from getting into oil.

In 1941, oil containing 2 per cent of dichloroethyl ether was tested in addition to the other materials. Pepper & Barber (1940) and Barber (1941) had found oil with dichloroethyl ether to be superior to oil with pyrethrins, and the former was considerably cheaper. The insecticides were prepared on the ranch.

RESULTS.—The results obtained in 1940 are shown in table 1. The two oils containing pyrethrum gave approximately the same results, but both were more effective than oil alone. The 100-viscosity oil was 20 cents per gallon cheaper than the 185-viscosity oil with pyrethrum. In the first field treated the undeveloped area at the tips of the ears was larger on

[2] Viscosity here and in other parts of this paper refers to Saybolt viscosity at 100° F.

the treated ears than on comparable untreated ears. This injury apparently was corrected in fields treated later by having the operators insert the tip of the oiler

Table 1.—Effectiveness against the corn earworm of the different treatments used in 1940 in four fields at Garden Grove.

Treatment	Per Cent of Ears Free from Earworm Injury	Inches of Undeveloped Corn at Tip of Ear
	Early-planted corn (6 replicates)	
185-viscosity oil	63.7	2.02
100-viscosity oil and pyrethrins 0.2%	82.9	1.73
Check	4.2	1.09
	Late-planted corn (16 replicates)	
185-viscosity oil and pyrethrins 0.2%	88.5	1.08
100-viscosity oil and pyrethrins 0.2%	91.2	1.12
Check	7.5	1.09

only about one-fourth inch into the end of the ear rather than an inch or more, as they were doing in the first field.

The results for 1941 are given in table 2. At both Indio and Garden Grove, oil containing pyrethrins was observed to give better control than oil containing dichloroethyl ether, but the difference was not of mathematical significance. At Indio, both reduced earworm injury considerably without causing measurable injury to the plants. At Garden Grove, however, both insecticides caused injury to the ears, oils containing dichloroethyl ether causing more damage than oils containing pyrethrins and the 100-viscosity oil causing more damage than 185-viscosity oil. This injury by the insecticides did not affect the marketability of the corn, as the treated corn consistently sold on the wholesale market for 5 to 10 cents more per dozen ears than the untreated corn. The greater oil damage in 1941 may be attributed to differences in the timing of the applications. The operators went into the field too early and apparently treated many of the ears prematurely.

COST OF OIL-PYRETHRUM TREATMENT.—At Garden Grove in 1940, when commercial preparations were used, the cost per acre of the oil-pyrethrum mixture for two applications was as follows: Labor, 28 hours at 31 cents per hour, $8.68; oil mixture, 3 gallons at $1.48 per gallon, $4.44. This was the commercial price per gallon in 26-gallon drum lots.

At Indio, where the insecticides were prepared on the ranch, and where the ears were not marked the first time through the field, the cost per acre for two applications was as follows: Labor, 19 hours at 33.3 cents per hour, $6.33; oil mixture, 2 gallons at $1.07 per gallon, $2.14. The oil was purchased in 50-gallon drum lots and the oleoresin of pyrethrum in gallon lots.

CONCLUSION.—These tests demonstrated that oil containing 0.2 per cent pyrethrins is superior to oil alone and to oil containing 2 per cent of dichloroethyl ether, when applied at the rate of three-fourths ml. per ear. If not carefully timed, all treatments may damage the tips of the ears. In southern California it is necessary to go over the fields twice in order to treat the ears at the right stage of development. The first application should be made when about 60 per cent of the ears are pollinized. The treated ears should be marked by one of the methods suggested, so that they may easily be skipped when the balance of the ears are treated after a 4- or 5-day interval. Treatment with the oil-pyrethrum mixture consistently protected 80 per cent or more of the ears from injury. This percentage is necessary in order that the corn may be marketed as "worm-free".—2-19-43.

Table 2.—Effectiveness against the corn earworm of the different treatments used in 1941 in six fields.

Treatment	Per Cent of Ears Free from Earworm Injury	Inches of Undeveloped Corn at Tip of Ear
	Indio (11 replicates)	
100-viscosity oil and pyrethrins 0.2%	74.2	1.43
100-viscosity oil and dichloroethyl ether 2%	64.9	1.54
Check	11.1	1.35
	Garden Grove (26 replicates)	
100-viscosity oil and pyrethrins 0.2%	86.3	1.65
185-viscosity oil and dichloroethyl ether 2%	73.5	1.61
100-viscosity oil and dichloroethyl ether 2%	71.0	1.81
Check[1]	2.0	.91

[1] Only one plot per field.

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Natural Control of Eggs and First Instar Larvae of *Heliothis armigera*[1]

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In studying the variations in infestations by the cotton bollworm it has been found that an abundance of eggs on the cotton plant is not necessarily followed by severe injury (Thomas & Dunnam, 1931). Attractiveness of the cotton plant to ovipositing moths is not alone enough to insure an infestation. In the investigations discussed in this paper certain of the biological factors affecting the eggs and first instar larvae and their relative importance were studied in the field.

In 1932 twenty-five points were selected in upland and bottomland cotton in the vicinity of College Station.[2] The procedure consisted in locating eggs and larvae, labeling their location on the plant and keeping them under observation as much as possible until they hatched or until their fate was known. The season was abnormally hot and dry and the oviposition did not exceed 8 eggs per 100 main terminals on as many plants at the points worked. Counting the eggs on about the top 6 inches of the main terminal of the cotton plant is a standard method of determining the probable infestation of *Heliothis armigera* Hbn. The cotton practically stopped growing and its leaves became dry and tough. After making observations nearly two months under these conditions, it was considered advisable to conduct similar observations in an area where more frequent rains had produced succulent cotton in contrast to the toughened plants of the College Station area and where egg deposition was greater. Such an area was located at Spur, Dickens County, and 8 days of observations were recorded. The oviposition at this latter place reached a maximum of 43 eggs per 100 terminals. In 1933 at Waco the weather was generally hot and dry and the cotton in a non-succulent condition. There was, however, considerable oviposition. The maximum number of eggs per 100 terminals in the blackland fields under observations reached 20. On succulent cotton this amount of oviposition is sometimes followed by severe bollworm injury.

In 1937 the work was resumed and continued through 1940. The observations made during these years were obtained at points located in cotton in the Brazos River bottom near College Station. The procedure was essentially the same as that used in 1932 and 1933.

During 1937 observations were made at 11 points in late cotton, which because of local showers was growing rapidly and in a succulent condition. The maximum number of eggs per 100 terminals was 31. The effect of the showers, however, soon ceased and the cotton became dry and unattractive to ovipositing moths. In 1938 the experiments were carried at 15 points. The oviposition was quite heavy; the maximum number of eggs per 100 terminals reached 47 and bollworm damage was severe. The cotton was very succulent. During the summer of 1939 observations were made at 12 points. The cotton was succulent and the maximum oviposition was 33 eggs per 100 terminals. In 1940 the maximum number of eggs per 100 ter-

[1] Technical Contribution No. 765, Division of Entomology, Texas Agricultural Experiment Station.
[2] The work was carried on by S. W. Bromley in 1932 at College Station and Spur. H. B. Mills recorded the observations in 1933 at Waco.

minals was 27. In 1940 records were made on eggs at 23 points. While the oviposition was not heavy, the cotton remained succulent and attractive to ovipositing moths in the areas studied.

In the 6 years these studies were carried on, 1938 eggs were tagged at three different typical cotton growing locations. The observations are recorded in table 1. The per cent of eggs known to have hatched varied from 26.4 in 1938 to 58.1 in 1939. Quaintance & Brues, 1905, showed that under protected conditions only 1.22 per cent of eggs laid by fertile females failed to hatch.

Egg parasitism was present each year. The higher percentages occurred at Spur in 1942 and in the Brazos River bottom in 1940 while during the other years the parasitism was very much lower. The higher parasitism at Spur can be explained by the fact that a large population of *Trichogramma minutum* (Riley) was built up in the eggs of the fall armyworm, *Laphygma frugiperda* (S. & A.) an outbreak of which had been in progress in the area where observations were made. It is possible that the higher percentage of egg parasitism found in the Brazos River bottom in 1940 was due to a similar occurrence though no outbreak in or near cotton of a known host of *Trichogramma* was observed.

The percentage of eggs recorded as destroyed by predators ranged from 32.9 at College Station in 1932 to 15.3 at Spur the same year. This figure includes eggs which were found collapsed. In 1938, 1939, and 1940 no eggs were found which the observer felt justified in so recording. It was observed that eggs after being attacked by *Orius insidiosus* (Say) would appear shrunken and flattened out. Based on careful observations the writers feel certain that most of the collapsed eggs found in the field had been attacked by *O. insidiosus* or by some other predator.

Of the eggs, from 11.2 per cent in 1939 to 43.7 per cent in 1938 were dislodged by wind, rain, cultivation, or unaccounted for. The cotton field in which the observations were made in 1938 was badly infested with Johnson grass. Because of this the grower cultivated the field at frequent intervals which resulted in dislodging many eggs. It is possible that light showers which occurred may have caused the eggs to become less firmly attached to the plants. A few eggs could not be found following high winds. This occurred in tall, dense stands of cotton. The wide variation in the percentages of eggs which were dislodged is of particular interest. Possibly some come to rest lower down on other parts of the plants, but undoubtedly most fall to the ground and the larvae upon hatching fail to reach the plants.

The most critical period in the life of the bollworm on cotton is the first larval instar. At this time the larva is more subject to the attack of predators, more sensitive to adverse environment, and more likely to be injured by mechanical agencies than at any other stage in its development. It is undoubtedly at this time that the degree of subsequent infestation is largely decided.

Observations on 814 first instar larvae made at the same 3 locations during the 6 years are summarized in table 2. The number of larvae range from 87 in 1932 to 151 in 1940. In 4 of the 6 years more than half of the larvae were lost due to wind, cultivation, and other causes. Those disappearing at College Station and Spur varied respectively between 6.6 per cent in 1940 and 87.4 per cent in 1932. One explanation for the low percentage lost in 1940 is due to the fact that more young

Table 1.—Observations on the natural control of eggs of *Heliothis armigera*.

	Spur	Waco	College Station				
	1932	1933	1932	1937	1938	1939	1940
Number eggs observed	152	262	285	228	435	258	378
Per Cent							
Hatched	40.4	35.1	36.0	45.2	26.4	58.1	39.9
Not hatched in 5 to 8 days	11.1	4.5	—	—	—	—	—
Parasitized	15.2	5.3	1.7	5.3	1.4	1.2	15.2
Collapsing or destroyed by predators	15.3	31.1	32.9	17.6	28.5	29.5	16.1
Unaccounted for	18.0	24.0	29.4	32.0	43.7	11.2	28.8

Table 2.—Observations on the natural control of first instar larvae of *Heliothis armigera*.

	SPUR	WACO	COLLEGE STATION				
	1932	1933	1932	1937	1938	1939	1940
Number of larvae observed	87	92	116	103	115	150	151
Per Cent							
Survived first instar	—	4.3	—	—	—	—	—
Entered squares	—	—	—	0	0	0	15.9
Dropped from plant	—	—	—	0	4.3	6.7	17.9
Destroyed by predators or other causes	12.6	17.6	35.9	35.0	40.0	49.3	59.6
Unaccounted for	87.4	78.1	64.1	65.0	55.7	44.0	6.6

larvae were observed to drop from the plant that year and are recorded elsewhere in the table.

Sometimes a larva would spin a thread and drop to a lower branch. In a few instances these larvae were observed to enter small bolls on these branches. This is certainly one way in which larvae become distributed over the plant, thus increasing the chance of survival.

Predators accounted for a large part of the larvae. The percentage so destroyed ranged from 12.6 in 1932 at Spur to 59.6 in 1940 at College Station.

Predators obviously play an important part in the natural control of both the eggs and first instar larvae of *Heliothis armigera*. In table 3 the comparative importance of predators observed is shown. *Orius insidiosus* acounts for by far the greatest percentage of both eggs and larvae. In 1939 it destroyed 28.3 per cent of the eggs and in 1940 52.3 per cent of the larvae.

Orius indisiosus breeds in great numbers on corn silks and as the corn matures disperses to cotton and other vegetation. Apparently it breeds in cotton for the nymphs are common in cotton fields. Both adults and nymphs are very active and may be found on all parts of the cotton plants especially on the growing tips of the plants.

The numbers of *Orius insidiosus* vary greatly in different cotton fields. They have been found in largest numbers in a field of succulent cotton growing next to a field of late corn in which the silks were drying up. Their abundance in cotton, however, does not depend entirely upon the proximity of corn. They may sometimes be found in abundance in cotton fields at considerable distances from corn. The numbers of this important predator, however, certainly increase in corn fields.

Lace wing fly larvae are sometimes present in considerable numbers on cotton. They were not observed to attack bollworms very extensively; in fact, in several instances they obviously were not attracted by nearby moving first instar larvae. It may be that some of the eggs and larvae included in the table as collapsed or unaccounted for were destroyed by lace wing larvae. So far as observed, however, they were not especially attracted by either the eggs or larvae of *Heliothis armigera*. Lace wing fly larvae apparently are more aphidophagus than general feeders.

In numerous instances spiders caught the larvae, but in general, spiders are more apt to prey upon the larger larvae. Although in 1937 they accounted for half as many young larvae as the *Orius insidiosus*.

No lady beetle larvae or adults were observed in these studies to attack any of the stages of *Heliothis armigera*. These predators were present in considerable numbers but as in the case of the lace

Table 3.—Percentages of eggs and larvae of *Heliothis armigera* destroyed by various predators at College Station.[1]

	1937		1938		1939		1940	
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
Orius insidiosus	7.5	23.3	24.6	36.5	28.3	42.0	16.1	52.3
Larvae of Lace Wing Flies	0	0	3.9	0	1.2	0	0	0
Spiders	0	11.7	0	3.5	0	7.3	0	7.3
Unknown (collapsed)	10.1	0	0	0	0	0	0	0

[1] No specific records of predators were made in 1932 and 1933.

Table 4.—Possible survival of early stages of *Heliothis armigera* in relation to oviposition and known hazards.

	Spur	Waco	College Station				
	1932	1933	1932	1937	1938	1939	1940
No. eggs per 100 terminals	43	20	8	31	47	33	27
Percentage of eggs known to be destroyed by parasites or predators	30.5	36.4	34.6	22.9	29.9	30.7	31.3
Maximum number of surviving eggs	29.9	12.7	5.2	23.9	32.9	22.9	18.5
Percentage larvae known to be destroyed by predators and other factors	12.6	17.6	35.9	35.0	40.0	49.3	59.6
Maximum possible number larvae developing from original eggs	26.1	10.5	3.3	15.5	19.7	11.6	7.5

wings they were seen on several occasions to ignore both eggs and larvae of *Heliothis armigera* even when in close proximity. They, too, seemed to be more attracted by aphids.

In a few cases larvae died while under observation. It was impossible to determine the cause for this. It occurred mostly on non-succulent cotton. It could not be starvation because the larvae, in some instances, died in an hour or two and larvae have been observed to live without food for much longer. Most of the larvae died during a period of high wind and high temperature.

Many larvae disappeared during the night when it was impossible to determine the cause. It is, of course, possible that certain predators are more active in the evening, night, and early morning.

In table 4 the possible numbers of *Heliothis armigera* larvae alive at the end of one day after hatching has been calculated and is shown in relation to the numbers of eggs originally found per 100 terminals in cotton. In 1932 at College Station with an oviposition of 8 eggs per 100 terminals and considering known natural control factors the maximum survival possible was 3.3 larvae. In the same year at Spur with an oviposition of 43 eggs per 100 terminals the maximum survival was 26.1 larvae. Furthermore, this survival at Spur was higher than that at College Station in 1938 when a maximum of 19.7 larvae survived following a count of 47 eggs per 100 terminals. These variations in natural control help to explain variation in injury which cannot be accounted for by differences in oviposition records alone. Assuming that all the eggs and larvae, which were not known to be destroyed by predators or parasites, hatched and completed development it may be stated on the basis of these studies that not more than 61 per cent of the eggs laid by *Heliothis armigera* develop beyond the first instar under field conditions.—2-15-43.

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Changes Announced in the Field Crop Insect Personnel

Dr. C. M. Packard, of the Division of Cereal and Forage Insect Investigations of the Bureau, has recently issued the following statements concerning changes in assignments of personnel within the Division.

Due to the imminent retirement of Mr. W. R. Walton as assistant leader of the Division of Cereal and Forage Insect Investigations, of the Bureau of Entomology and Plant Quarantine, Mr. W. A. Baker is being transferred from Toledo, Ohio, to Washington, D. C., to assume the duties of this position.

Mr. W. G. Bradley is being placed in general field charge of our European corn borer investigations, vice Mr. Baker, with headquarters at Toledo, Ohio. These headquarters were moved from 1920 Parkwood Avenue to 2256 Collingwood Avenue, Toledo, Ohio in June.

Mr. C. A. Clark is being transferred from Moorestown, N. J., to Toledo, Ohio, to act as Mr. Bradley's first assistant. He is also being made directly responsible for our European corn borer parasite investigations both within the Division and in cooperation with State agencies.

A Study of Methods of Sampling Mosquito Populations[1,2]

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The great difficulty encountered in efforts to analyze a mosquito population, so as to be able intelligently and effectively to attack the control problem at the sources of mosquito production, is largely appreciated only by those persons intimately acquainted with the ecology of mosquitoes. Many of the established methods of sampling have been severely and justifiably criticized on the grounds of the selectivity of the methods. For example, the use of live bait may be highly selective for one species under a given set of conditions but more selective for another under other conditions. The results obtained may vary with the individual host (*e.g.* with its size, body temperature, carbon dioxide output, portion of the animal exposed and color), and also are influenced by the degree of protection from winds, disturbing lights, etc. during the taking of the record. Many other factors, such as the time of day, lightness of the environment and meteorological conditions also are known to complicate the analysis. The suggestion of Headlee (1941 b) that the records of mosquitoes present in barns, pig houses, nail kegs and similar places may represent special concentrations of *Anopheles quadrimaculatus* Say is only too clearly shown by the results herein reported. Other methods of sampling have likewise been criticized.

For more than a decade the New Jersey mosquito trap has been used as a practical and very popular device for gaining information for use in the planning and operation of mosquito abatement programs in the Atlantic coastal states. The development of this means of sampling mosquito populations must rank with the major recent accomplishments in the mosquito control field. Many improvements in the design of the trap have been made, and its use has consistently increased from year to year—a basic proof of its utility. An account of the "evolution" of this trap can be followed in the papers by Headlee (1932) and Mulhern (1934).

The discovery of the role of carbon dioxide as an aid to the mosquito in locating its host, and the subsequent use of this material in mosquito traps are among the additional accomplishments of the New Jersey workers. The tests of Huffaker (1941), indicating the lack of attraction of either carbon dioxide or light to *Anopheles quadrimaculatus*, were conducted too late in the season to be of value. A higher degree of attraction to both light and carbon dioxide, particularly the latter, is exhibited by the results of this present study. The major points in favor of the use of the New Jersey trap have been (1) the ease with which records may be obtained and (2) the degree to which such a record is devoid of the usual errors incurred by the use of any non-mechanical device. It has been assumed by the great majority of mosquito control workers using the trap that, because of the very nature of the method, the various species are caught in numbers proportional to their respective occurrences in the heterogeneous mosquito population.

This assumption is based upon fallacious grounds. It must be remembered that the trap is only one component of the picture. The other component, the mosquitoes, possesses all the degrees of variation particularly common to living things. Cognizant of the great diversity in the complex behavior of different species of organisms, it would be hard to see why it is not wholly logical to expect that different species of mosquitoes will exhibit marked variations in their responses to light stimuli. That different insects do so vary in their reactions to light is common knowledge. It is, furthermore, a fundamental biological principle that ecological variation is not a respector of phylogenetic ties. Hence, it may be expected that marked differences in behavior exist even within a genus.

[1] This paper is the result of work carried on under the joint sponsorship of the Delaware Agricultural Experiment Station and the Delaware State Highway Department, Mosquito Control Division, and is published with the approval of the Director of the Station and the Chief Engineer of the Highway Department. The problem was instigated as one having a definite relation to the war effort, in view of the military emphasis on the evaluation of mosquito conditions at the points of troop concentrations throughout the world. The work was carried out under the supervision of Dr. Paul L. Rice, Acting Head of the Department of Entomology of the Experiment Station.

[2] The authors wish to express their indebtedness to Donald MacCreary for the suggestion of the general problem; and to Dr. Rice, Harvey L. Chada, Edward W. Bushing, and Gilbert Thornton for assistance in the collection of the data.

It is, therefore, of foremost importance that the entire picture of mosquito behavior in relation to light traps, utilizing both monochromatic and white light, should be established. Headlee (1937) found that red light is 6.1, green-yellow light is 12.3, and blue light is 21.5 times as attractive to mosquitoes as is white light. However, it seems unlikely that the reaction of mosquitoes to light is adequately described by a straight line throughout the range of intensity studied by Headlee. Unless such a foundation is established, his results will remain highly questionable. Otherwise, to establish the relative attractive powers of differently colored lights, it would be necessary to utilize the respective portions of the spectrum at equivalent intensities. In this connection, Gui *et al.* (1942) concluded, "The colors on which comparable data are available arrange themselves in order of least to most attractiveness to insects as red, yellow, white, and blue." White light was found to be very conclusively far superior to yellow. There are, however, questions to be raised as to the employment of any light intensity meters used at the present time.

This whole question of the degree of reliance that can be placed upon records from New Jersey traps is enshrowded with the complexities of mosquito behavior, which is well attested by the widely conflicting views of prominent mosquito abatement workers. LePrince & Orenstein (1916) published an account of their observations in the Panama Canal Zone to the effect that anophelines are not attracted to strong lights or to lighted rooms, whereas culicines are. Herms & Gray (1940) concluded, "We are convinced that there are still too many unknown factors relating to the light reaction of mosquitoes, and other stimuli which may attract or repel them, to place much confidence in either the quantitative or qualitative aspects of their (New Jersey mosquito traps) catches."

A principal consideration in the employment of such a trap, therefore, should be the establishment of dependable ratios or correction factors, so as to make it possible to bring the records for any species to a comparable standing with those for any and all other species. It is of course plausible that this cannot be done with a high degree of accuracy, because of these inherent complexities of mosquito behavior, but it certainly should be possible to make a more satisfactory interpretation than that obtained in the use of non-corrected records.

The white light reaction values and correction factors presented in this paper are most assuredly deserving of criticism. The basic object in presenting these preliminary data is to point out the necessity for correcting New Jersey mosquito trap records, and to develop a method for use in doing so. The whole question has only been touched upon. However, as a result of this work, it should be possible to devise simple experiments, using New Jersey traps with and without lights, to establish practical correction factors for the more important species. These correction factors might then be applied to more extensive data obtained by the use of the light traps alone. Coincident with or prior to the continuation of studies of this kind, the more basic behavior of the individual species should be studied under controlled conditions, in relation to light and other commonly prevailing environmental stimuli.

METHODS.—As a site for conducting these tests a farm adjacent to Fort du Pont Delaware, was selected. This farm is within a quarter of a mile of extensive breeding areas of both the permanent and temporary water types. It is located on the outskirts of Delaware City, where New Jersey trap records for 10 previous seasons had shown a great abundance and variety of mosquitoes.

The following methods of sampling were tried:

1. Four New Jersey traps placed in a group, each one about 35 feet from the others, equipped as follows:
   a. With a 25-watt white frosted light.
   b. With a 25-watt white frosted light and carbon dioxide (3 lb. block of dry ice).
   c. With carbon dioxide (3 lb. block of dry ice).
   d. With no attractant (only the fan was used).

The attractants were rotated from one trap and location to another in a counterclockwise manner, the change being made each night of operations. To a large extent it is believed, this procedure reduced the differences due to the individual trap efficiency and locations that would otherwise have occurred.

2. Two New Jersey traps, isolated from the above and each about 100 feet from any others, equipped as follows:

a. With a 25-watt white frosted light.
b. With no attractant (only the fan was used).

3. Catches were made, by means of an aspirator, of those mosquitoes which fed or attempted to feed on the legs of the senior author during a 10-minute period of each hour. A flashlight was covered with a folded handkerchief and used to furnish a dim light for use in making the collections. *Anopheles quadrimaculatus* seemed to be far more hesitant in seeking to feed or to continue feeding under the rays of the uncovered flashlight than were the other species. During times of heavy intensity of attack a smaller part of those feeding were caught than at other times.

4. A 12-inch insect net was used to sweep the air to get additional collections for comparative purposes. The net was swung in the form of a large figure 8, thus sampling air from the 1 to 8 foot levels. Sweepings were made for about 5 minutes of each hour.

5. Counts and estimates of the total numbers of mosquitoes present in the near-by cattle barn were made on each day of the tests. A sizable sample of these were collected and determined. The collections and estimates were made about an hour before sundown—while the mosquitoes were still inactive.

6. Four nail kegs were placed in sheltered spots about the lot. The mosquitoes in these were chloroformed, counted and determined for each day of the tests, the collections being made about an hour before sundown.

The New Jersey traps were operated during the first three hours after dusk for a total of 10 nights at 7 to 10-day intervals from July 9 to September 24, 1942. This study was prolonged throughout the greater portion of the season in order to obtain data under as great a variety of conditions as possible. The traps were run without screens above the fans. Observations had indicated that more *Anopheles* than other forms are caught on the screens and are able to walk away from the influence of the fan. The longer legs of *Anopheles* would possibly account for this.

The receptacles used with these traps were the usual pint-sized cyanide killing jars. A small wad of cotton, lightly soaked with chloroform, was dropped into each jar just prior to the removal of the catches at the end of each hour. A similar piece of cotton was also placed in each pill box container in which the mosquitoes were stored until the identifications were made. The material was determined within two weeks of the time of the collections. This procedure ensured a maximum number of undamaged specimens for determination purposes.

INFLUENCE OF METHOD ON RESULTS.—Table 1 presents the results of the present study, involving the collection and determination of 49,053 mosquitoes.

Five of the methods shown were used in getting an average which is presumed to be far nearer a true representative figure than the records obtained by any one method, with the exception of the isolated trap operated with no attractant. The latter trap, operated in a location distant from an appreciable attractant factor in the immediate vicinity, should be expected to give the most non-selective result of any method used. Such a trap catches those mosquitoes that happen to fly into the draft of the fan. The small number of mosquitoes so captured would preclude the practical use of such a trap.

The records from the isolated trap with no attractant have been used, however, as the basis of comparison in setting up light reaction values and correction factors discussed in a later section. At a later date, it would seem to be better to operate about four of these traps to one New Jersey trap operated in the usual manner in order to get a larger and more representative sample for comparative purposes. The close correspondence between the records for the isolated, no-attractant trap and the five-method averages seems to show very clearly that, for those species that were relatively numerous, the no-attractant trap is a dependable method of analysis from the qualitative aspect. In the cases where the correspondence is not so close, too few mosquitoes were captured to discount the general similarity in results.

At first thought it might be expected that air sweepings would give representative samples. However, the capture of many engorged females and of males, far out of proportion to the numbers taken by other methods, led the writers to the conclusion that the sweeper scares up certain species resting in the vegetation as he moves along. These forms are thus caught in greater numbers by such a method than a species, such as *Anopheles quadrimaculatus*, which does not rest in these situations. Sweepings taken from a moving automobile possibly may be more satisfactorily utilized.

The very striking differences in the composition of mosquito samples, depending upon the method used in making the sample, is well illustrated by the data of table 1. That this variation is so great as to establish the lack of comparability of rec-

ords obtained by these commonly used methods is obvious. Publishing the results of mosquito studies in the Seventh Corps Area in 1941, Carpenter (1942) stated, "Mosquito traps of the New Jersey type compared favorably with hand collection methods for measuring adult densities of *Anopheles quadrimaculatus*." The writers not necessarily be even remotely close to the weekly catch or estimate in a barn, pigpen or other such shelter. Near Fort duPont, Delaware in 1942 an average of 4,834 females of this species were estimated per weekly inspection of the barn adjacent to the Fort, whereas the light trap at the Fort caught an average of only

Table 1.—Total female mosquitoes captured and percentages for each species, under each method of sampling: collections made near Fort duPont, Delaware, 1942.

	Percentages of the 10-Night Totals for the 3-Hour Period After Dusk								10-Night Sample from Barn[2]	10-Night Catch in Nail Kegs	Five-Method Average	
Species	Light (G)	Light and CO_2 (G)	CO_2 (G)[1]	No attractant (G)	Light (I)[1]	No attractant (I)[1]	Biting Records[1]	Sweepings[1]	in Per cent	in Per cent	in Per cent	Totals
Anopheles												
quadrimaculatus	9.7	8.4	44.7	51.4	10.3	26.1	30.3	20.1	92.9	97.2	26.3	8017
crucians	6.9	4.1	3.6	1.9	6.7	3.3	0.6	1.9	2.9	0.2	3.3	2081
walkeri	1.6	1.5	0.9	0.6	2.7	0.5	0.4	0.0	0.0	0.0	0.9	669
punctipennis	[3]	[3]	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.6	[3]	27
spp.	0.8	0.3	0.2	0.2	0.1	0.0	0.2	0.0	0.0	0.0	0.1	156
Aedes												
vexans	14.5	8.1	7.4	6.4	19.5	10.9	6.0	23.0	0.2	0.0	13.4	4380
sollicitans	0.8	1.5	2.3	3.1	0.8	0.9	3.8	7.4	0.0	0.0	3.0	789
cantator	1.3	0.4	0.4	0.6	0.5	1.9	1.7	1.2	0.5	0.2	1.1	249
taeniorhynchus	0.2	0.1	0.1	0.2	[3]	0.0	0.2	0.6	0.2	0.0	0.2	73
trivittatus	0.0	0.0	[3]	0.0	0.0	0.0	0.2	0.0	0.0	0.0	[3]	2
triseriatus	0.0	[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	[3]	1
Culex												
salinarius	60.2	71.9	36.7	32.2	36.1	46.9	52.8	44.2	2.5	0.8	47.3	30861
pipiens	[3]	[3]	[3]	0.0	0.0	2.4	0.0	0.0	0.0	0.6	0.5	18
apicalis	0.0	[3]	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.3	4
spp.	2.3	1.5	0.9	0.4	1.3	3.8	0.2	0.1	0.0	0.0	1.3	691
Psorophora												
columbiae	0.1	0.2	0.1	0.6	0.5	0.0	0.0	0.1	0.0	0.0	0.1	92
ciliata	[3]	[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6
Mansonia												
perturbans	1.2	1.9	2.2	2.3	1.3	0.5	3.5	0.7	0.6	0.2	1.6	909
Uranotaenia												
sapphirina	0.0	[3]	0.0	0.0	0.0	0.6	0.0	0.1	0.0	0.0	0.1	4
Mutilated specimens	0.2	[3]	0.1	0.2	[3]	0.9	0.2	0.4	0.0	0.0	0.3	33
Totals	4333	33437	6548	518	1648	211	521	721	645	471	—	49053

[1] Methods used to determine the five-method average.
[2] These figures represent the determined samples only, there being an average estimated number (not herein presented) of 4834 mosquitoes present at each weekly inspection.
[3] Less than 0.1 per cent.

in no way contradict this statement, but would like to point out that it is readily subject to the misinterpretation that Carpenter found that the New Jersey trap catches this species on a basis comparable with other forms. Such an interpretation would be wholly erroneous, for Carpenter's data have no bearing upon the ability of the New Jersey trap to catch a representative sample of a mixed population. He was not concerned in this instance with a mixed population. In addition, the close numerical correlation between his hand and trap collections is pure coincidence, *i.e.* the weekly average of this species caught in a New Jersey trap would 105 per week of operation during the same period of time. Other barns in the same general vicinity averaged much higher in numbers, but no comparable mosquito trap records are available.

Comparing the methods of sampling, as presented in table 1, *Anopheles quadrimaculatus* showed the greatest variation of any species, from 8.4 per cent of the total for carbon dioxide and light (G) or 10.3 per cent for light (I) to 92.9 per cent for the barn or 97.2 per cent for the nail kegs. On the basis of the least selective of all methods used (the isolated, no-attractant trap) there was one species, *Culex salinarius* Coq., which was nearly twice as abundant,

representing 46.9 per cent of the population (compared to 26.1 per cent for the malarial form), and a second, *Aedes vexans* (Meig.), was nearly half as abundant, representing 10.9 per cent of the total population. Nevertheless, these two species were not found in appreciable numbers in either barns or nail kegs. *Anopheles crucians* Wied. was the only other species, which was caught in significant numbers, that was attracted to the barn to an extent comparable with its abundance in the general population.

Therefore, neither barns nor nail kegs are in any way useful in obtaining a representative sample of mosquitoes. This statement carries the additional weight of experience, not presented herein, with the use of 50 nail kegs, in conjunction with other observations, during an entire season and regular seasonal inspection of barns, pigpens, and similar mosquito resting quarters for a period of 5 years.

On the other hand, it seems evident that the use of such adult resting quarters in establishing the densities of *Anopheles quadrimaculatus*, when its abundance relative to other species is of little concern, is a far more satisfactory method than the use of New Jersey mosquito traps. Such mosquito resting quarters in the Fort duPont, Delaware area have registered fluctuations in numbers of this vector as great as from none to 40,000. The maximum ever caught on a single night by a New Jersey trap in the same area has been around 100. When the numbers present in a favorable barn are small, *i.e.* from 25 to 200, as is often the case in malarious regions, the New Jersey trap could hardly be expected to catch a sufficient number of this species to serve as a useful device in the anti-malarial campaign. This fact is at the root of the failure of anti-malarial organizations in *quadrimaculatus* territory to accept and use the trap. With other important vectors, however, the trap might prove to be highly useful.

As further evidence of the lack of conformity in results, depending upon the method of sampling used, it can be seen from table 1 that all species which were caught in appreciable numbers show marked variations. The following maximal variations in percentages of the total catches are indicated: *Anopheles crucians* —0.2 to 6.9, *A. walkeri* Theob.—0.0 to 2.7, *Aedes vexans*—0.0 to 23.0, *Aedes sollicitans* (Walk.)—0.0 to 7.4, *Culex salinarius* —0.8 to 71.9, and *Mansonia perturbans* (Walk.)—0.2 to 3.5. Therefore, it is inconceivable to attempt comparisons of results obtained by the use of methods which reveal such gross variations in the relative importance of the component species of the sample. Those methods which have proven themselves useful in particular instances should be retained, but a continual search should be made to establish a more widely acceptable method of sampling.

INFLUENCE OF PREVAILING CONDITIONS ON RESULTS.—There may be a very noticeable variation from night to night in the reaction of the same species to light or other stimuli. This variation may prove to be so great as to render the correction of light trap records, for example, of little value. On one night in the present study, a trap with carbon dioxide alone caught 593 female *Anopheles quadrimaculatus;* one with carbon dioxide and light, 184; and one with light alone, only 56. It will be noted that the figure for carbon dioxide and light is three times as great as that for light alone; and that for carbon dioxide alone is three times as great as that for both carbon dioxide and light. On every night the trap with light alone caught the least of the three traps, but the trap with carbon dioxide and light, on several occasions, caught more of this species than did the trap with carbon dioxide alone. On one night, for example, it caught 349, 2.5 times the 134 caught by the carbon dioxide trap. Clearly, on certain nights, the light acted as a repellent when used with carbon dioxide, while on other nights it served as an added attractant.

The results in table 1 reveal that, on the basis of all nights, there was little difference in the catches of these two traps, but the trap with both carbon dioxide and light caught 106 fewer of this species than did the carbon dioxide trap. Of the other species, the carbon dioxide and light trap caught from 3 to 10 times as many as did the trap with carbon dioxide alone, the approximate ratios being as follows: 3 to 1 for *Aedes sollicitans*, 4 to 1 for *Aedes cantator* Coq. and *M. perturbans*, 6 to 1 for *Aedes taeniorhynchus* (Wied.), *Aedes vexans* and *Anopheles crucians*, 8 to 1 for *Anopheles walkeri*, and 10 to 1 for *Culex salinarius*. As a stimulating factor, therefore, the season's summary showed that the light,

when used in conjunction with carbon dioxide, registered less than nil only for *Anopheles quadrimaculatus*.

That a light alone is somewhat attractive to this species, at least under certain conditions, is shown by the fact that the isolated light trap (Table 1) caught 169 *Anopheles quadrimaculatus*, whereas the isolated, no-attractant trap caught only 55. However, during the progress of these tests general observations were made that may prove to be significant in explaining such reactions of this or other species to the New Jersey trap. For this species, there is an indication that the light trap is more effective on dark nights than on light. On 5 of 6 nights classified as medium dark or light the trap with carbon dioxide alone excelled the trap with both carbon dioxide and light. Also, on 3 of 4 nights classified as dark, the reverse was the case. Furthermore, on 4 of 6 medium dark or light nights the trap with no attractant exceeded the light trap in catches of this species, while on 3 of 4 dark nights the reverse was the case. Hence, on light nights the use of a light in conjunction with carbon dioxide, or alone, seemed to have a repellent effect, while on dark nights it acted as an attractant.

It seems probable that the point of intensity at which a given light becomes attractive or repellent is not an absolute value, independent of the pre-adjusted condition of the mosquito or irrespective of the species concerned. Rather, in some cases at least, it seems to be related to the contrast in the light intensities of the trap and of the general surroundings. That there is a point of repellency of bright lights to mosquitoes in general is discussed by Headlee (1937). This subject is one which demands a separate study for many species in order to arrive at well-founded conclusions regarding heterogeneous populations. The data herein presented are exceedingly fragmentary, and are presented only as an *indication* to stimulate further study.

LIGHT TRAP REACTION VALUES AND CORRECTION FACTORS.—Unfortunately, the least selective method of sampling used in this work is one that catches very few mosquitoes, and could only be used in establishing correction factors for light traps in areas where mosquitoes are very numerous. As previously stated, the isolated, no-attractant trap caught each of the more important species in this area in the same proportions, generally, as is indicated by the average percentages derived from five methods. In arriving at these averages those methods which were influenced by a combination of attractant factors and those which were unusually selective (catches from the barn and nail kegs) were omitted.

Theoretically, as well as empirically, the trap which utilized the fan alone is the least selective method used. Only the draft of the fan was present either as an attractant or repellent. There is little evidence that mosquitoes detect the effective draft of the fan until they have already flown into it and cannot escape.

Using the records of the isolated, no-attractant trap as a basis of comparison, the light reaction values and correction factors for several species are presented in table 2. These results reveal that the New Jersey trap (with a 25-watt white frosted bulb) catches *Anopheles walkeri* 5.40 times more readily than it should on the basis of the proportion of this species in the general population; whereas *A. quadrimaculatus* is caught only 0.39 as readily as is its representation in the total population (see column of light reaction values). Other species fell between these two extremes. Although only one specimen of *A. walkei* was collected by the trap with no attractant, the fact that 45 were collected by the light trap, together with the very large numbers caught by the carbon dioxide and light trap, as compared to carbon dioxide alone, would seem to establish the high attraction of this species to light. Also, New Jersey light trap records in the Delaware City area in 1941, viewed in relation to comparable dipping results for *A. walkeri* and *A. quadrimaculatus* larvae during the same season, give further support to the position of *A. walkeri* as one very highly attracted to the New Jersey trap.

The records for *Mansonia perturbans* and *Aedes sollicitans* are very meager, and either species may actually occupy some other position in the list. This presentation as a whole is a preliminary one. It is only hoped that the reactions of these and many other species will receive a much more extended, clear-cut study along the lines that have developed in the course of this work.

The light correction factors as presented

Table 2.—White light reaction values and correction factors for females of several species of mosquitoes, as calculated from the catches of a New Jersey trap operated with a 25-watt light as compared to one operated with no attractant.[1,2]

SPECIES	NO ATTRACTANT (I)		LIGHT (I)		LIGHT REACTION VALUES	LIGHT TRAP CORRECTION FACTORS
	Number	Per Cent	Number	Per Cent		
Anopheles walkeri	1	0.5	45	2.7	5.40	0.19
Mansonia perturbans	1	0.5	21	1.3	2.60	0.48
Anopheles crucians	7	3.3	110	6.7	2.03	0.49
Aedes vexans	23	10.9	322	19.5	1.79	0.56
Culex salinarius	99	46.9	924	56.1	1.20	0.84
Aedes sollicitans	2	0.9	13	0.8	0.89	1.13
Anopheles quadrimaculatus	55	26.1	169	10.3	0.39	2.53
All others	23	10.9	44	2.7	—	—
Totals	211	100.0	1648	100.0	—	—

[1] These data are taken from records obtained at Delaware City, Delaware, 1942.
[2] Method of calculations: *e.g. Anopheles walkeri*—2.7 per cent/0.5 per cent = 5.40 (light reaction value); and 0.5 per cent/2.7 per cent = 0.19 (light trap correction factor).

in table 2 are directly derivable from the light reaction values or from the percentage data, and represent the values by which the actual data, obtained by the use of the light trap, must be multiplied in order to arrive at results which would be more in conformity with a representative sample.

It sometimes is desirable to compare the attraction of a trap for a given species in terms of some other species. The ratios of attraction to the New Jersey trap between any one of the seven species listed and any other are set forth in table 3. It may be seen that *Anopheles walkeri*, the most highly attracted species is 13.85 times as reactive as is *A. quadrimaculatus*, the least attracted one. Other species occupy intermediate positions, as may be seen by following the vertical column under *A. walkeri*.

REPULSION OF MALE MOSQUITOES BY CARBON DIOXIDE.—It has been generally known that male *Anopheles quadrimaculatus* do not gather in barns, pigpens, and similar shelters in numbers, except with the advent of adverse weather. However, nail kegs or barrels, if in properly shaded locations, even in the immediate vicinity of a barn which does not attract them, will attract large numbers of males of this species. A total of 264 males and 450 females were taken from the four nail kegs used in this study—32.1 per cent males. On the other hand, only 22, or 3.5 per cent, of the 621 determined specimens of this species captured in the barn, were males.

A repulsion to male mosquitoes and the attraction to females of concentrations of carbon dioxide may have some possible relation in this connection. The attraction of females is, of course, well established, as

Table 3.—Relative New Jersey mosquito trap reaction values of several species of mosquitoes, in terms of the reaction of each other species.[1,2]

SPECIES WHOSE LIGHT REACTION VALUES ARE TAKEN AS UNITY	VALUES ARE THE NUMBER OF TIMES THE SPECIES BELOW ARE AS REACTIVE AS THOSE AT THE LEFT						
	A. walkeri	*M. perturbans*	*A. crucians*	*A. vexans*	*C. salinarius*	*A. sollictans*	*A. 4-maculatus*
Anopheles walkeri	1.00	0.48	0.38	0.33	0.22	0.16	0.07
Mansonia perturbans	2.08	1.00	0.78	0.69	0.46	0.34	0.15
Anopheles crucians	2.66	1.28	1.00	0.88	0.59	0.44	0.19
Aedes vexans	3.02	1.45	1.13	1.00	0.67	0.50	0.22
Culex salinarius	4.50	2.17	1.69	1.49	1.00	0.74	0.33
Aedes sollicitans	6.07	2.92	2.28	2.01	1.35	1.00	0.44
Anopheles quadrimaculatus	13.85	6.67	5.21	4.59	3.08	2.28	1.00

[1] These data are based upon records obtained at Delaware City, Del., 1942.
[2] Values are calculated by dividing the light reaction value of a given species (as presented in table 2) by the correspondng value of each other species. Thus, 5.40 (for *A. walkeri*)/2.60 (for *M. perturbans*) = 2.08, or *A. walkeri* is 2.08 times as reactive to the trap as is *M. perturbans*. Also, the reaction of *A. walkeri* is to 2.08 as that of *M. perturbans* is to 1. In like manner, *A. crucians* is 0.38 times as reactive as is *A. walkeri*.

shown by reference to papers by Headlee (1934, 1941) and Huffaker (1941). An examination of the data obtained in this study has led the authors to the conclusion that males are, on the contrary, distinctly repelled. A total of only 3 males, of all species, were captured by the carbon dioxide trap, 17 by the isolated trap with no attractant, 67 with the carbon dixoide and light trap and 119 with the isolated light trap. The carbon dioxide trap, therefore, caught only one-sixth as many as did the trap with no attractant, and the trap with both carbon dioxide and light caught one-half as many as did the trap with light alone.

PERIODS OF PEAK MOSQUITO ACTIVITY.—The general rule of a very marked dusk period of maximal mosquito activity does not seem to apply to all species, for *Anopheles quadrimaculatus* apparently is an exception. On the basis of 10-day records, obtained by several methods, for the first 3 hours after dusk, all other species declined in numbers after the first hour, and this decline was very pronounced for such forms as *Aedes sollicitans*, *A. vexans*, *A. taeniorhynchus*, *Anopheles walkeri*, and *Psorophora columbiae* (D. & K.). The decline was less marked for such forms as *Anopheles crucians*, *C. salinarius*, and *M. perturbans*. In contrast, there was a slight increase in numbers, or at least an equality, from the first to third hours for *A. quadrimaculatus*. Hourly records throughout two entire nights showed that the activity of this latter species in mid-summer was maintained until well after midnight at which time a decline set in. This species as well as the others observed, had a revival of activity at the dawn period. The records of these hourly observations are not presented in this paper.

SUMMARY.—A study of the mosquito populations at a point adjacent to Fort duPont, Delaware, was made at 7 to 10-day intervals from early July to late September, 1942, the purpose being to determine the degree of dependence that can be placed in the catches of the New Jersey mosquito trap. The traps were operated in several ways—(1) in the usual manner with a white, frosted, 25-watt light bulb as the attractant, (2) with both the light and carbon dioxide as attractants, (3) with carbon dioxide alone and (4) with no attractant (only the fan was used). In addition, catches of mosquitoes attempting to bite, catches through sweeping, and collections from a cattle barn and nail kegs were obtained to compare with the catches from the New Jersey traps.

Results have revealed that none of these methods can be depended upon for an adequate, non-selective analysis of a heterogeneous mosquito population. A trap with no attractant seems to give the best qualitative results, but it catches too few mosquitoes to be of practical use in itself.

A consideration of the empirical data as well as purely theoretical concepts has convinced the writers that the New Jersey mosquito trap does not catch a respresentative sample of a mixed mosquito population. Different species may be attracted to different degrees, depending upon the prevailing conditions and the species.

Comparing the different methods of sampling used, *Anopheles quadrimaculatus* showed the greatest variation of any species, varying from 8.4 per cent of the total catch for the carbon dioxide and light trap, or 10.3 per cent for the isolated light trap, to 92.9 per cent for the barn, or 97.2 per cent for the nail kegs. *Culex salinarius*, a species twice as abundant in the general population, was not caught in appreciable numbers in either the barn or nail kegs. It varied from 0.8 per cent of the total catch for the nail kegs to 71.9 per cent for the carbon dioxide and light trap. Other species also showed marked differences. The catches from barns, nail kegs and similar resting quarters showed the highest degree of specific selection of any method used. However, on the basis of comparison with catches by the least selective method used, *A. walkeri*, for example, was caught even by the New Jersey trap approximately 14 times as readily as was *A. quadrimaculatus*. Tables of the relative attraction to the New Jersey trap of the different species encountered are presented. A method of correction of the records obtained by the New Jersey traps is presented which may prove feasible in large-scale survey work. By this method such records may be placed on a more satisfactory basis—*i.e.* one more representative of the occurrence of the various species in the general population.

A possible relationship between the surrounding light intensity of the night (as compared to that of the trap) and the catches of these traps was indicated in that the trap is more effective in catching

A. quadrimaculatus on dark nights than on light ones.

The activity of this species is also shown to continue relatively unabated for a period of two or more hours after that of many other species has greatly declined.

Male mosquitoes, showing a reaction opposite to that of females, are definitely repelled by concentrations of carbon dioxide.—2-6-43.

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Studies of Parasites of the American Dog Tick[1]

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Only two species of insects, *Hunterellus hookeri* Howard and *Ixodiphagus texanus* Howard, are known to parasitize ticks. *Ixodiphagus caucurtei* Du B., described as a third tick parasite, is now regarded as a synonym of *H. hookeri* by Gahan (1934). Both these encyrtids attack immature ticks of several species.

Several attempts have been made to utilize *Hunterellus hookeri* in the control of ticks, but none have met with marked success. Although this species is often naturally prevalent among nymphs of the brown dog tick, *Rhipicephalus sanguineus* (Latr.), it has not been reported to reduce the tick infestations effectively. Hooker *et al.* (1912) and Philip (1931) have recorded such instances. Larrousse *et al.* (1928) reported the overwintering of a colony liberated on the Elizabeth Islands, and Cobb (1942) recovered the parasites on the islands 12 years later, but the American dog tick, *Dermacentor variabilis* (Say), and the black-legged tick, *Ixodes scapularis* Say, remained abundant. Cooley & Kohls (1933) reported the release of millions of parasites in areas infested by the Rocky Mountain spotted-fever tick, *Dermacentor andersoni* (Stiles), but did not indicate that effective tick control was obtained. Bishopp (1934) reported the recovery of the parasites in *D. variabilis* on Capers Island, S. C., 2 years after their release there by J. C. Bequaert, but ticks were still abundant.

Notwithstanding these discouraging reports, it appeared possible that *Hunterellus hookeri* might be utilized in the control of *Dermacentor variabilis* if a colony could be established and maintained by repeated releases. Such an attempt was made in 1937, 1938, and 1939 on the island of Martha's Vineyard, Mass.

BIOLOGY OF *HUNTERELLUS HOOKERI*—Biological observations were incidental to the rearing and release of parasites, as a fairly complete biology was available from the works of Wood (1911) and Cooley & Kohls (1933). The strain of parasites used was obtained from naturally parasitized nymphs of *Rhipicephalus sanguineus* from Texas, and had been maintained for about 12 generations in nymphs of *Dermacentor variabilis* at Washington, D. C., when this experiment was started.

[1] The writers are indebted to A. B. Gahan for identifications of all parasites collected in the field and of sample specimens obtained from the laboratory colony.

In the following observations nymphs of *Dermacentor variabilis* were used as hosts, unless otherwise noted.

The proportion of parasitized nymphs from which the parasites emerged successfully varied greatly, but experimental rearing under various conditions indicated that a temperature of 80° F. and a relative humidity of 70 per cent provided the optimum conditions for development. In some lots kept under these conditions 100 per cent of the parasites emerged, therefore a cabinet where that temperature and humidity were maintained was used for stock rearing. The period from dropping of engorged, parasitized nymphs to emergence of parasites ranged from 20 to 30 days.

Ninety-five male and 836 female parasites emerged from 44 nymphs in one lot, an average of 2 males and 19 females for each nymph, and 105 males and 627 females emerged from 38 nymphs in another lot, an average of 3 male and 17 female parasites for each nymph. Based on the emergence in both lots, 2 males and 18 females should have been produced by each nymph from which parasites emerged, and this figure was used in calculating the number of parasites released in the experimental area.

Parasitized nymphs were exposed to temperatures of 50° and 60° F. for periods of 19 to 21 days without injury to the parasites, when exposure to the low temperature followed soon after dropping, but when an interval of 12 to 22 days at higher temperature intervened all or nearly all the parasites were killed. Exposure to a temperature of 40° for 19 days killed all the parasites in engorged nymphs. The records on the survival of the immature parasites in ticks stored at intermediate temperatures are summarized in table 1. Parasitized nymphs kept outdoors in earth-bottomed tubes favorable to tick rearing produced adult parasites when the engorged ticks dropped in June or July, but when they dropped and were exposed outdoors in May, August, September, or October no parasites were produced, therefore there was no overwinter survival of parasites in engorged nymphs.

Adult parasites lived 24 to 48 hours at 80° F., 6 days at 60°, 23 days at 50°, and 6 days at 40°, but were killed by exposure of 24 hours or over at 35°.

Table 1.—Survival of immature *Hunterellus hookeri* in engorged nymphs of *Dermacentor variabilis* stored at intermediate temperatures.

Date Nymphs Dropped from Host	Number of Parasitized Nymphs	Pre-storage Period[1] (Days)	Temperature of Storage (°F.)	Storage Period (Days)	Percentage of Nymphs from Which Parasites Emerged
1937					
Dec. 22	15	0	40	27	0
Do.	15	0	50	27	0
Do.	15	0	60	27	0
Dec. 23	16	—	80	—	50
1938					
Jan. 19	4	—	80	—	100
Jan. 20	31	—	80	—	87
Do.	10	2	40	19	0
Do.	10	2	50	19	90
Do.	10	2	60	19	20
Do.	7	2	60	21	43
Do.	5	7	60	21	100
Do.	5	12	60	22	0
Do.	5	17	60	21	20
Do.	5	22	60	21	0
Jan. 22	10	23	60	2	90
Feb. 14	10	11	50	8	40
Do.	10	11	50	21	0
Do.	16	11	50	35	0
Feb. 15	14	18	50	7	50
Do.	14	18	50	14	0
Do.	14	18	50	21	0
Do.	14	18	50	28	0
Do.	14	18	50	35	0
Do.	13	18	50	42	0
Feb. 17	51	—	80	—	86
Feb. 19	5	6	50	22	0
Do.	10	11	50	21	0
Do.	10	16	50	22	0
Do.	10	21	50	21	0
Feb. 20	46	—	80	—	83
Mar. 17	74	20	50[2]	6	70
Mar. 18	44	19	50[2]	6	55
Mar. 20	37	17	50[2]	6	14
Apr. 9	30	—	80	—	97
Apr. 17	18	0	50[2]	3	55
Do.	18	0	50	6	77
Do.	18	0	50	9	22
Do.	18	0	50	12	22
Do.	18	0	50	15	0
Do.	18	0	50	18	0
Do.	18	0	50	21	0
Do.	18	0	50	24	0

[1] Period between dropping of engorged nymphs from the host and their storage at a low temperature, during which time they were kept at a temperature of 80° F.
[2] Stored at 40° F. the first day.

Large numbers of tick larvae were exposed to active female parasites while engorging on meadow mice, but no signs of parasitization were observed in the larvae or in the nymphs they produced, even after the latter had been engorged. However, some larvae failed to molt and some flat nymphs died.

Three mice were infested with nymphs in the laboratory and exposed in a field for 24 hours in cages placed at distances of 50 and 100 feet from a point where parasites were emerging, but none of the 73 nymphs on them became parasitized. On two occasions 5 meadow mice infested with nymphs were exposed for 24 hours within a 10-foot circle around the site of a parasite release. Adult parasites and nymphs from which emergence was taking place were released each time, but none of the

nymphs on the mice became parasitized.

Parasites emerged from 1 of 40 nymphs of *Ixodes muris* B. and S., from 1 of 21 nymphs of *Haemaphysalis leporis-palustris* (Pack.), but from none of 67 nymphs of *I. dentatus* Marx exposed to active adult parasites while engorging on mice or rabbits in parasitization cages.

METHODS OF REARING.—In rearing *Hunterellus hookeri* to be released in the experimental area, it was found that large numbers of parasitized nymphs could be most easily produced by exposing the nymphs of *Dermacentor variabilis* to ovipositing females while the ticks were engorging on hosts. In some instances large numbers of nymphs engorged successfully on rabbits, but in many instances the nymphs that dropped from rabbits were abnormally bloated and died in a few days. Meadow mice were preferred as hosts, as the nymphs that dropped from them were invariably normal, and 5 mice were as easily obtained and handled, and produced as many engorged nymphs, as did the average rabbit. The tick-infested mice were confined in small cages of hardware cloth, 5 of which could be exposed at one time to active adult parasites in larger parasitization cages of glass, wood, and cloth. Parasitization was permitted during the second and third days of tick feeding, then the caged mice were removed and the ticks permitted to complete engorgement and drop. Of 32,129 nymphs exposed in this manner, 19,535 became parasitized. The engorged nymphs were kept in pill boxes on moist sand in a cabinet at a temperature of 80° F. and a relative humidity of 70 per cent until the parasites were about due to emerge, then they were moved to glass vials. The parasites were reared through 25 generations by this method, but in the last few generations reduced oviposition and emergence indicated a pronounced loss of vitality.

FIELD RELEASES AND RECOVERY.—Three methods of release were employed. Sometimes the adult parasites were permitted to emerge in the laboratory and were then released in the experimental area. This method produced a high proportion of parasite emergence, but the females had expended a large portion of their longevity before they were released. Sometimes parasitized nymphs were exposed in mouse runs. They were kept in envelopes of copper screening, which permitted the adult parasites to escape as soon as they emerged but retained the nymphs for observation on the percentage of emergence. This method produced fresh adult parasites in a natural habitat, but a low proportion of parasites emerged. A third method consisted of trapping mice in the area, infesting the mice with nymphs, parasitizing the nymphs, and releasing the mice carrying the parasitized ticks at the exact site of their capture. In this way the parasites would be exposed to exactly the conditions they would ordinarily encounter, but no estimate of the proportion of emergence could be obtained.

Releases were made in two locations on Squibnocket Beach, Chilmark, Mass., where the American dog tick was abundant. In the first locality, a wild cranberry bog, releases were made in September and October, 1937, and in April, May, June, and July 1938. A total of 5,846 nymphs were exposed and parasites emerged from 2,444, giving an estimated release of 44,000 females. Fifty-five meadow mice, each carrying about 20 parasitized nymphs, were also released. In the second locality, an area of grassy hills near a beach, releases were made in August 1938 and from May to August 1939. A total of 5,892 nymphs were exposed and parasites emerged from 2,591, giving an estimated release of 47,000 females. About 6,000 active females were also released, together with 32 mice carrying from 20 to 25 parasitized ticks each.

Adult parasites emerged from only 43 per cent of the parasitized nymphs exposed in the two localities. The average monthly proportion of emergence ranged from 78 per cent (in July 1938) to 22 per cent (in June 1939). The lowest proportion of emergence each year occurred in June.

Populations of *Dermacentor variabilis* show considerable variation under normal conditions. In 1937 the bog area was fairly heavily infested, but in 1938, when the releases were made, immature ticks were scarce even though adult ticks remained abundant. Only 24 nymphs were found on mice during the time the parasites were being released, and none of these were parasitized. The hurricane of September 1938 filled the bog with sand, effectively killing both ticks and mice and precluding further observations. All stages of ticks

were abundant in the beach area in 1938, and during the time parasites were being released (August) 85 nymphs were taken on mice, but none were parasitized. The hurricane did not cover this area with either sand or water, but the grass showed considerable injury thereafter, probably due to salt spray. Mice and immature ticks were scarce in 1939, but adults remained abundant. Only 27 nymphs were taken on mice during the entire season of parasite releases, and none of these were parasitized. In 1940 ticks were again abundant and 160 nymphs were taken but none were parasitized. In 1941, 125 nymphs were taken, none were parasitized, and all stages of ticks remained abundant.

PERSISTENCE ON THE ELIZABETH ISLANDS.—Larrousse *et al.* (1928) reported the recovery of (*Ixodiphagus caucurtei*) *Hunterellus hookeri* in nymphs of *Dermacentor variabilis* and *Ixodes scapularis* on the Elizabeth Islands in 1927, following its release in 1926. Cobb (1942) reported that adults of *H. hookeri* were taken from the hair of a dog on the islands in 1940. The present writers recovered the parasites there in 1941, 1 male and 4 females emerging from a nymph of *I. scapularis* taken on a meadow mouse, but 284 other nymphs of *I. scapularis* and 2,143 nymphs of *D. variabilis* taken on mice on the islands were not parasitized by this species. Both species of ticks have remained abundant.

INDIGENOUS PARASITE OF *DERMACENTOR VARIABILIS*.—*Ixodiphagus texanus* is indigenous to this region. On Martha's Vineyard it has repeatedly been taken in larvae and nymphs of *Haemaphysalis leporis-palustris*, and on one occasion it was reared from a nymph of *Ixodes dentatus*, but it has never been found parasitizing *Dermacentor variabilis*. On the Elizabeth Islands, however, 1 of 4,507 larvae and 6 of 2,143 nymphs of *D. variabilis* were parasitized, together with 6 of 2,659 larvae of *Ixodes scapularis*. None of 285 nymphs of *I. scapularis* were parasitized. The ticks were taken on meadow mice and white-footed mice.

SUMMARY.—In an attempt to control the American dog tick, *Dermacentor variabilis* (Say), 90,000 females of *Hunterellus hookeri* were released in two localities on Martha's Vineyard, Mass., in 1937, 1938, and 1939. No parasites were recovered in ticks collected in the area from 1937 to 1942, and no reduction in tick abundance attributable to the parasites was observed. No parasites survived the winter in experimental rearing. Ticks on mice within a few feet of emerging parasites were not parasitized. The strain of *H. hookeri* used in this experiment originated in Texas. The strain of *H. hookeri* from France, released by Larrousse and others on the Elizabeth Islands in 1926, has apparently persisted, as one parasitized nymph of *Ixodes scapularis* was collected there, but no nymphs of *Dermacentor variabilis* were infested. *Ixodiphagus texanus*, an indigenous species, was found in larvae and nymphs of *D. variabilis* on the Elizabeth Islands, but not on Martha's Vineyard, where this tick is also abundant and the parasite is also found.—3-4-43

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New Distribution Records for the Mosquitoes of the Southeastern United States During 1942[1]

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The extensive mosquito collecting program carried out by the various installations of the United States Army in eight of the Southeastern States has added considerably to our knowledge of the distribution of the mosquito fauna of this region. Because of the immediate value of such data in a mosquito control program it is felt that these new records should be made available at once. King and Kuhns (1943) have fully explained the development of the entomological program in the Fourth Service Command so the purpose of the present paper is chiefly to present the many new records accumulated.

King *et al.* (1942) have listed the previous records for the mosquitoes of this region. Their table showing the distribution of the various species is here revised (Table 1) to include our new records.

During the year 1942, a total of 204,679 adults and 39,498 larvae, representing many thousands of individual collections, were identified or confirmed at the Fourth Service Command Laboratory. The specific records on which the revision of Table 1 is based are listed below. These data were taken from collections of the following types: (L) = larval; (R) = reared adults; (T) = light traps; (S) = resting stations; (B) = biting.

In the following records, the letter in parentheses preceeding the number of specimens taken and the date, designates the type of collection represented. To conserve space, many of the records have been consolidated into monthly periods. However, with the relatively rare species or where the number of collections are comparatively few, the individual collection dates are given.

[1] It is desired to express appreciation to Colonel Sanford W. French, M.C., Chief, Medical Branch, Fourth Service Command, Colonel Charles G. Souder, M. C., Medical Branch, Fourth Service Command, and Colonel Dwight M. Kuhns, M.C., Commanding Officer, Fourth Service Command Laboratory, for their assistance in making possible the development of the mosquito collection program of the Fourth Service Command.

Appreciation is further expressed to Brig. Gen. James S. Simmons, M. C. and Colonel W. A. Hardenbergh, Sn. C, Preventive Medicine Section, Office of The Surgeon General, U. S. Army, Washington, D. C.

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Aedes atlanticus D. and K.

At the present time *A. atlanticus* cannot be distinguished from *A. tormentor* except by characters to be found in the larvae and male genitalia. The following adult records, therefore, are all based upon male specimens, confirmed by an examination of the genitalia.

MISSISSIPPI—*Mississippi Institute of Aeronautics*, Jackson, Hinds Co.: (T) 2, June 23; 1, Aug. 21. *Jackson Army Air Base*, Jackson, Hinds Co.: (T) 4, June 16–19; 1, July 10; 1, Aug. 19; 1, Sept. 2 *Camp Shelby*, Hattiesburg, Forrest Co.: (L) 1, June 11; 3, July 18. (T) 1, May 28; 2, July 11–12.

Aedes canadensis (Theob.)

ALABAMA—*Craig Field*, Selma, Dallas Co.: (S) 1 ♂, Sept. 4. *Fort McClellan*, Anniston, Calhoun Co.: (L) 2, June 2, 16. *Maxwell Field*, Montgomery, Montgomery Co.: (T) 2 ♂♂, June 2. *Camp Rucker*, Ozark, Dale Co.: (L) 5, Oct. 8; 9, Dec. 23, 30. GEORGIA—*Fort Benning*, Columbus, Muscogee Co.: (R) 1 ♀, Sept. 4. *Daniel Field*, Augusta, Richmond Co.: (L) 6, June 18; 1, Aug. 29. (S) 1 ♂, Aug. 22. (B) 2 ♀♀, Aug. 29. *Fort McPherson*, Atlanta, Fulton Co.: (L) 86, April 9, 27. (B) 2 ♀♀, July 16. (T) 1 ♂, Sept. 9. *Lawson General Hospital*, Atlanta, Fulton Co.: (R) 3 ♀♀, May 11. *Hunter Field*, Savannah, Chatham Co.: (T) 1 ♀, Aug. 19. *Fort Oglethorpe*, Chattanooga, Hamilton Co.: (S) 7 ♀♀, Sept. *Warner Robins Air Depot*, Macon, Bibb Co.: (B) 4 ♀♀, June 11–29. *Moody Field*, Valdosta, Lowndes Co.: (L) 1, July 22; 8, Oct. 29; 3, Dec. 10. *Spence Field*, Moultrie, Colquitt Co.: (L) 3, May 30; 79, June 13, 20. *Camp Stewart*, Hinesville, Liberty Co.: (T) 2 ♂♂, April 9, 29; 3 ♀♀, June 13, 14, 18; 1 ♀, July 14; 1 ♂, July 30. (B) 4 ♀♀, May 4; 3 ♀♀, July 3, 13. (S) 3 ♂♂, June 10; 1 ♂, July 16. *Camp Wheeler*, Macon, Bibb Co.: (L) 4, May 25; 1, June 16. (R) 2 ♂♂, June 18. (S) 1 ♂, May 25. *Camp Gordon*, Augusta, Richmond Co.: (L) 4, May 28; 2, June 2; 4, July 6. (T) 1 ♀, June 18. (B) 2 ♀♀, May 30.

Aedes cinereus Meig.

This species has previously been unrecorded from the Fourth Service Command, the nearest collections being from Arkansas. The new records greatly extend the known range of this interesting species. The males were positively identified by the genitalia and in addition, showed the unique short palpi which are similar to those of most female culicines.

GEORGIA—*Fort McPherson:* (T) 1 ♂, July 17. SOUTH CAROLINA—*Fort Jackson*, Columbia, Richland Co.: (T) 1 ♂, June 18.

Aedes dupreei (Coq.)

GEORGIA—*Camp Stewart:* (T) 2 ♀♀, June 27, 30; 1 ♂, July 15. (S) 1 ♀, June 6. *Camp Wheeler:* (B) 1 ♀, Sept. 4. MISSISSIPPI—*Jackson Army Air Base:* (T) 1 ♂, 1 ♀, June 18, 30; 2 ♂♂, July 10, 14. *Greenville Army Flying School*, Greenville, Washington Co.: (T) 1 ♂, Aug. 20. *Camp Shelby:* (T) 1 ♂, June 15; 3 ♂♂, 1 ♀, July 2, 3, 12. (B) 1 ♀, June 26.

Table 1.—Genera and species of mosquitoes occurring in nine southeastern states.

GENUS AND SPECIES	OCCURRENCE[1]								
	Florida	Georgia	Alabama	Mississippi	Louisiana	Arkansas	Tennessee	North Carolina	South Carolina
Aedes:									
aegypti	x	x	x	x	x	x	x	x	x
atlanticus	x	x	x	*	x	x	P	x	x
atropalpus						x	x	x	
canadensis	x	x	P	x	x	x	P	x	x
cinereus	x	*	*	x	x	x	x	x	x
dorsalis		*			?	x			*
dupreei					?				
fulvus pallens	x	*	P	*	x	x	P	x	x
grossbecki				x	x	o			
infirmatus	x	x	P	x	x	x	P	x	x
mitchellae	x	x	x	*	*			x	*
sollicitans	x	x	x	x	x	x		x	x
sticticus	x	x	*	*	x	x	x	x	*
stimulans				x					
taeniorhynchus	x	x	x	x	x	x		x	x
thibaulti		x	x	x	x	x	P	x	P
tormentor	x	x	x	x	x	x			x
triseriatus	x	x	x	x	x	x	x	x	x
trivittatus		x			x	o	*	*	
vexans	x	x	x	x	x	x	x	x	x
Anopheles:									
albimanus	x								
atropos	x	P	x	x	x			*	x
barberi	x	x	x	x	x	x	x	x	x
bradleyi	x	*	x	x	x			P	x
crucians	x	x	x	x	x	x	x	x	x
georgianus	*	x	*	*	*			*	*
pseudopunctipennis				x	x	o	x		
punctipennis	x	x	x	x	x	x	x	x	x
quadrimaculatus	x	x	x	x	x	x	x	x	x
walkeri	x	x	P	*	x	x	x	P	P
Culex:									
apicalis	x	x	x	*	x	x	x	x	x
atratus	*								
bahamensis	x								
erraticus	x	x	x	x	x	x	x	x	x
nigripalpus	x	x	x	P	x				x
peccator	x	x	x	x	x	x	x	x	x
pilosus	x	x	x	*	x			x	x
pipiens		*	*				x	x	*
quinquefasciatus	x	x	x	x	x	x	x	x	x
restuans	x	x	x	x	x	x	x	x	x
salinarius	x	x	x	*	x	x	*	x	x
tarsalis					x	x	*		
Deinocerites:									
cancer	x								
Mansonia:									
perturbans	x	x	x	*	x	x	x	x	x
titillans	x								
Megarhinus:									
rutilus	x	x							
septentrionalis		x	x	x	x	x	x	x	x
Orthopodomia:									
alba			x						
signifera	x	x	x	x	x	x	x	x	x

Table 1.—*Continued*

GENUS AND SPECIES	OCCURRENCE[1]								
	Florida	Georgia	Alabama	Mississippi	Louisiana	Arkansas	Tennessee	North Carolina	South Carolina
Psorophora:									
ciliata	x	x	x	x	x	x	x	x	x
confinnis	x	x	x	x	x	x	x	x	x
cyanescens		*	x	x	x	x			
discolor	x	x	x	x	x	x	x	x	*
ferox	x	x	x	x	x	x	x	x	x
horrida		*	*	x		x	x	*	
howardii	x	x	P	x	x	x	x	x	x
pygmea	x								
signipennis						x			
varipes	x	x	x	x	x	x	x	*	
Theobaldia:									
inornata	x	*	x	x	x	x	*	x	x
melanura	x	x	x	*	x	x	*	x	x
Uranotaenia:									
lowii	x	*	*	*	x				
sapphirina	x	x	x	x	x	x	x	*	x
Wyeomyia:									
mitchellii	x								
smithii			x					x	x
vanduzeei	x								
Total Species	50	48	43	47	48	45	34	42	43

[1] x indicates records by King *et al.* (1942); * New records Fourth Service Command Laboratory; o Recorded by S. J. Carpenter (1942); ? Doubtful records (King *et al.* 1942); P Probably occurs, but not recorded.

Aedes mitchellae (Dyar)

A. mitchellae breeds in rain water pools and while not found breeding in salt marshes its range is generally thought to be restricted to the Coastal Plain. However, some of these new records indicate this species may breed for a considerable distance inland.

LOUISIANA—*Camp Claiborne,* Alexandria, Rapides Co.: (T) 2 ♀ ♀, April 14, 16. *Camp Livingston,* Alexandria, Rapides Co.: (T) 1 ♂, April 25. MISSISSIPPI—*Jackson Army Air Base:* (T) 1 ♀, July 22. *Mississippi Institute of Aeronautics:* (T) 1 ♀, June 15. *Camp Shelby:* (L) 1, April 7. (T) 6 ♀ ♀, April 10, 20, 21; 3 ♀ ♀, May 8, 29; 1 ♀, June 6; 1 ♂, June 13; 1 ♀, 1 ♂, July 6. SOUTH CAROLINA—*Fort Jackson:* (T) 3 ♀ ♀, June 10, 24; 4 ♀ ♀, July 13–15; 22 ♀ ♀, 14 ♂ ♂, Aug. 12–Sept. 4; 1 ♂, 4 ♀ ♀, Sept. 23; 2 ♂ ♂, 4 ♀ ♀, Nov. 10–25. *Fort Moultrie,* Charleston, Charleston Co.: (T) 6 ♀ ♀, Sept. 21.

Aedes sticticus (Meig.)

ALABAMA—*Camp Rucker:* (B) 2 ♀ ♀, May 12. MISSISSIPPI—*Camp Shelby:* (T) 32 ♂ ♂, 219 ♀ ♀, April 16–May 2; 2 ♂ ♂, 28 ♀ ♀, May 3–30; 1 ♂, 11 ♀ ♀, June 2, 12, 25. (S) 1 ♂, 52 ♀ ♀, April 17; 72 ♀ ♀, May 5–June 1. (B) 13 ♀ ♀, April 30; 6 ♀ ♀, June 2; 9 ♀ ♀, Sept. 12. SOUTH CAROLINA—*Camp Croft,* Spartanburg, Spartanburg Co.: (T) 1 ♂, May 13; 1 ♂, June 5.

Aedes trivittatus (Coq.)

NORTH CAROLINA—*Camp Butner,* Durham, Durham Co.: (B) 2 ♀ ♀, June 22, Sept. 1. TENNESSEE—*Camp Tyson,* Paris, Henry Co.: (S) 1 ♀, June 25.

Anopheles atropos D. and K.

NORTH CAROLINA—*Camp Davis,* Wilmington, New Hanover Co.: (T) 3 ♀ ♀, Aug. 30; 21 ♀ ♀, Sept. 8–27; 30 ♀ ♀, Oct. 2–29; 1 ♂, 1 ♀, Nov. 9, 19.

Anopheles bradleyi King

GEORGIA—*Hunter Field:* (T) 1 ♀, Dec. 10.

Anopheles georgianus King

A. georgianus has previously been recorded from several counties in Georgia. It has now been taken from several other states in the Southeast. The adult is indistinguishable from *A. crucians* but the larvae possess distinctive taxonomic characters. The following records are all based upon larval identifications. Its role as a malaria vector is unknown.

ALABAMA—*Camp Rucker:* 51, May 10–21; 1, Aug. 17; 7, Sept. 2, 30; 119, Oct. 9–30; 54, Nov. 5–Dec. 4; 7, Dec. 7–30. FLORIDA—*Fort Barrancas,* Pensacola, Escambia Co.: 1, May 22. *Camp Blanding,* Starke, Bradford Co.: 1, April 20; 18, May 5–25; 2, June 2, 17. GEORGIA—*Daniel Field:* 2, June 9, 16; 3, Aug. 22, 29; 2, Sept. 12, 18; 2, Oct. 3. *Warner Robins Air Depot:* 1, June 12. *Spence Field:* 1, June 20. *Camp Wheeler:* 6, May 23. *Camp Gordon:* 6, May 25–29; 66, June 1–30; 32, July 8–30; 63, Aug. 3–27; 36, Sept. 2–19. LOUISIANA—*Camp Livingston:* 20, April 11, 14. *Camp Polk,* Leesville, Vernon Co.: 14, Jan. 21–Feb. 12; 39, March 12–April 9. MISSISSIPPI—*Camp Shelby:* 48, April 4–30; 28, May 4–19; 31, June 5–30; 30, July 9–18. NORTH CAROLINA

—*Fort Bragg*, Fayetteville, Cumberland Co.: 54, Oct. 9–30; 52, Nov. 2–30; 6, Dec. 23. *Camp Sutton*, Monroe, Union Co.: 1, Sept. 14. SOUTH CAROLINA—*Fort Jackson:* 2, June 10; 9, July 15, 23; 11, Aug. 12, 27; 9, Nov. 2–25.

Anopheles walkeri Theob.

MISSISSIPPI—*Camp Shelby:* (T) 2 ♀, May 8; 1 ♀, June 16.

Culex apicalis Adams

MISSISSIPPI—*Camp Shelby:* (L) 387, Mar. 24–May 27; 301, June 1–July 18. (R) 11 ♂♂, 14 ♀♀, May 9–July 1. (T) 9 ♂♂, 5 ♀♀, April 18–May 28; 12 ♂♂, 9 ♀♀, June 3–July 27. (S) 6 ♂♂, 16 ♀♀, April 12–July 13. *Jackson Army Air Base:* (L) 2, May 26; (T) 12 ♂♂, 3 ♀♀, May 25–27; 1 ♀, 5 ♂♂, June 5–23; 9 ♂♂, 5 ♀♀, July 13–22; 1 ♂, 4 ♀♀, Oct. 5–12. *Mississippi Institute of Aeronautics:* (T) 1 ♂, July 28. *Columbus Army Flying School*, Columbus, Lowndes Co.: (T) 1 ♂, Aug. 8; 8 ♀♀, Sept. 22, 29; 1 ♂, 2 ♀♀, Oct. 12–17. *Key Field*, Meridian, Lauderdale Co.: (T) 1 ♂, Nov. 26. *Greenville Army Flying School*, Greenville, Washington Co.: (T) 1 ♂, June 11; 5 ♂♂, 7 ♀♀, July 13, 22; 5 ♂♂, 16 ♀♀, Oct. 6–25. *Mississippi Ordnance Plant*, Flora, Madison Co.: (S) 2 ♀♀, Sept. 30. *Camp McCain*, Grenada, Grenada Co.: (L) 30, Aug. 6–26; 40, Sept. 2–25; 35, Oct. 7–28; 8, Nov. 3–14. (R) 4 ♂♂, 19 ♀♀, Aug. 26–Oct. 29. (S) 4 ♂♂, 13 ♀♀, Sept. 1–24; 15 ♂♂, 37 ♀♀, Oct. 1–29; 11 ♂♂, 51 ♀♀, Nov. 3–19; 4 ♀♀, Dec. 10.

Culex atratus Theob.

This is a new record for continental North America (Roth and Young 1943). It has previously been recorded by Dyar (1928) from the Virgin Islands (St. Thomas), Jamaica, Cuba and Haiti where it breeds in fresh water ground pools.

FLORIDA—*Boca Chica Key:* (T) 1 ♂, Dec. 9.

Culex pilosus (D. and K.)

MISSISSIPPI—*Columbus Army Flying School:* (T) 1 ♂, Oct. 20. *Camp Shelby:* (L) 1, June 22. (T) 1 ♂, July 6.

Culex pipiens L.

Culex pipiens, the common northern house mosquito, has previously been recorded from Tennessee (Caryville and Concord) and North Carolina (Smithfield and Lake Lure). The present new records have extended the range of this species much farther south than it has been known to exist. Since the larvae and adult females of *C. pipiens* are difficult to distinguish from those of *C. quinquefasciatus*, the following records are all adult males and have been identified by examination of the genitalia.

ALABAMA—*Fort McClellan:* (R) 4, Aug. 29. GEORGIA—*Fort McPherson:* (R) 3, Dec. 22. *Fort Oglethorpe:* (T) 5, Sept. NORTH CAROLINA—*Camp Sutton:* (T) 322, Aug. 5–Oct. 16. *Camp Butner*, Durham, Durham Co.: (S) 57, Sept. 10–Oct. 14. *Fort Bragg:* (S) 6, Sept. 22–Nov. 16. (R) 34, Aug. 7–Oct. 10. SOUTH CAROLINA—*Camp Croft:* (R) 2, Sept. 25. (T) 3, Aug. 14; 1, Sept. 16. (S) 3, July 28; 1, Aug. 15; 3, Sept. 17. *Fort Jackson:* (T) 1, July 29; 2, Dec. 3. (S) 1, Aug. 20; 3, Nov. 17. TENNESSEE—*Camp Tyson:* (T) 29, Aug. 31–Nov. 9. (S) 59, June 25–Oct. 18. *Camp Forrest*, Tullahoma, Coffee Co.: (T) 1, July 15; 1, Sept. 12; 1, Sept. 19; 1, Oct. 10; (S) 6, July 25; 3, Aug. 15.

Culex salinarius (Coq.)

MISSISSIPPI—*Camp McCain:* (L) 1, July 31; 15, Aug. 18–26; 8, Sept. 1, 8; 5, Oct. 21–28. (R) 1 ♂, 2 ♀♀, Aug. 27; 1 ♂, Sept. 7. (S) 1 ♂, Aug. 29; 4 ♂♂, 3 ♀♀, Sept. 1–24; 1 ♂, 15 ♀♀, Oct. 14–Nov. 3. (B) 20 ♀♀, Aug. 7–Sept. 17. *Camp Shelby:* (L) 5, May 13–28; 16, June 9, July 3; 1, July 13; (R) 7 ♂♂, 5 ♀♀, June 13. (T) 299 ♂♂, 469 ♀♀, April 16–July 18. (S) 20 ♂♂, 66 ♀♀, April 17–July 16. *Greenville Army Flying School:* (T) 1 ♂, May 26; 1 ♀, Sept. 3; 21 ♂♂, 14 ♀♀, Oct. 2–19. (S) 1 ♀, May 22. (B) 2 ♀♀, June 11, 18. *Keesler Field*, Biloxi, Harrison Co.: (L) 30, June 5; 17, Aug. 1–15. (S) 3 ♀♀, May 22; 1 ♂, 4 ♀♀, July 11; 2 ♀♀, Aug. 15. *Mississippi Institute of Aeronautics:* (T) 17 ♂♂, 11 ♀♀, June 15–July 2; 14 ♂♂, 15 ♀♀, July 7–Aug. 4. *Columbus Army Flying School:* (T) 3 ♀♀, Aug. 15–30; 3 ♂♂, 7 ♀♀, Sept. 11–26; 4 ♂♂, 2 ♀♀, Oct. 14–26; 1 ♂, Nov. 6. (S) 4 ♂♂, 4 ♀♀, Sept. 14–15; 2 ♂♂, 1 ♀, Oct. 1, 6. *Jackson Army Air Base:* (T) 8 ♂♂, 5 ♀♀, May 25–27; 23 ♂♂, 27 ♀♀, June 3–25; 3 ♂♂, 4 ♀♀, July 3–29; 8 ♀♀, Aug. 15–31; 1 ♂, 10 ♀♀, Sept. 7–23; 33 ♂♂, 44 ♀♀, Oct. 5–Nov. 5. TENNESSEE—*Camp Forrest:* (L) 1, May 23. (T) 1 ♀, July 15; (S) 2 ♀♀, June 22; 4 ♀♀, July 11. *Camp Tyson:* (L) 1, July 22; 1, Sept. 5; 1, Oct. 6. (T) 5 ♂♂, Aug. 17–26; 19 ♂♂, 16 ♀♀, Sept. 2–Oct. 3; 9 ♂♂, 10 ♀♀, Oct. 5–31; 1 ♂, 1 ♀, Nov. 6, 7. (S) 1 ♂, 1 ♀, May 25; 1 ♂, 1 ♀, June 5, 25; 1 ♀, 2 ♂♂, July 3, 15; 10 ♀♀, 8 ♂♂, Sept. 10–26; 3 ♀♀, Oct. 1, 6. (B) 2 ♀♀, May 28; 1 ♀, June 16.

Culex tarsalis (Coq.)

Culex tarsalis, a common western species has recently been found to carry the virus of both St. Louis encephalitis and western equine encephalomyelitis.

TENNESSEE—*Camp Tyson:* (L) 2, Oct. 6. (T) 1 ♀, Sept. 23. (S) 1 ♂, Sept. 21.

Mansonia perturbans (Walk.)

MISSISSIPPI—*Camp Shelby:* (T) 5 ♀♀, May 12–29; 1 ♀, June 22; 1 ♀, July 15. (S) 1 ♀, May 20; 7 ♀♀, June 12. (B) 1 ♀, June 25.

Psorophora cyanescens (Coq.)

GEORGIA—*Fort McPherson:* (T) 1 ♀, June 23; 1 ♀, July 8. *Warner Robins Air Depot:* (T) 1 ♀, Aug. 22; 1 ♀, Aug. 26. *Camp Stewart:* (T) 1 ♂, 1 ♀, July 9, 11. *Camp Wheeler:* (T) 1 ♀, June 20. (B) 1 ♀, July 29. *Camp Gordon:* (S) 1 ♀, Aug. 5.

Psorophora discolor (Coq.)

SOUTH CAROLINA—*Camp Croft:* (T) 3 ♀♀, June 2, 16, 20; 3 ♀♀, July 15, 21; 1 ♂, 7 ♀♀, Aug. 13–15. *Fort Jackson:* (R) 2 ♂♂, 1 ♀, June 18. (T) 8 ♀♀, May 26; 23 ♀♀, June 1–26; 7 ♂♂, 18 ♀♀, July 8–24; 1 ♀, Aug. 4; 9 ♀♀, Sept. 2–11. (S) 1 ♀, Aug. 26.

Psorophora horrida (D. & K.)

ALABAMA—*Brookley Field:* (B) 4 ♀♀, July 30. *Craig Field:* (B) 3 ♀♀, July 3; 1 ♀, July 17; 1 ♀, July 24. *Camp Sibert*, Gadsden, Gadsden Co.: (B) 1 ♀, July 25. GEORGIA—*Warner Robins Air Depot:* (B) 1 ♀, Sept. 30. *Camp Wheeler:* (S) 1 ♀, June 17. (B) 1 ♀, Sept. 4. *Camp Gordon:* (B) 1 ♀, June 19. NORTH CAROLINA—*Camp Sutton:* (B) 2 ♀♀, Sept. 14. *Fort Bragg:* (B) 6 ♀♀, Aug. 26, 27; 1 ♀, Sept. 2.

Psorophora varipes (Coq.)

NORTH CAROLINA—*Fort Bragg:* (B) 1 ♀, Aug. 27; 1 ♀, Sept. 23.

Theobaldia inornata (Will.)

GEORGIA—*Fort Benning:* (T) 1 ♀, Oct. 30; 1 ♀, Nov. 11. *Fort McPherson:* (L) 3, Dec. 22. *Hunter Field:* (T) 2 ♀♀, Oct. 29; 4 ♀♀, Nov. 5–24; 17 ♀♀, Dec. 1–26. *Camp Gordon:* (T) 1 ♀, Oct. 28. TENNESSEE—*Camp Tyson:* (T) 3 ♀♀, Sept. 24, 26; 13 ♀♀, Oct. 13–31; 20 ♀♀, Nov. 3–9.

Theobaldia melanura (Coq.)

MISSISSIPPI—*Jackson Army Air Base:* (T) 1 ♂, June 12; 5 ♀♀, Sept. 10. *Camp McBain:* (S) 1 ♂, Sept. 23; 2 ♂♂, 1 ♀, Oct. 6, 20. *Columbus Army Flying School:* (T) 1 ♂, Oct. 21. *Camp Shelby:* (L) 72, May 5–June 22; (T) 2 ♂♂, 8 ♀♀, April 15–May 2; 1 ♂, 11 ♀♀, May 4–18; 2 ♂♂, 10 ♀♀, June 3–July 4; 7 ♀♀, July 5–16; (S) 1 ♂, 1 ♀, April 1, 28; 4 ♀♀, June 1–29; 2 ♂♂, 3 ♀♀, July 14–16.

Uranotaenia lowii (Theob.)

Uranotaenia lowii has previously been reported only from the coastal areas in Florida, Louisiana and South Carolina. Some of the new 1942 locality records are of interest because they are a considerable distance inland.

ALABAMA—*Maxwell Field:* (T) 2 ♀♀, Oct. 20. GEORGIA—*Ft. Benning:* (R) 1 ♀, Oct. 13. (T) 1 ♀, Aug. 13; 3 ♀♀, Sept. 5; 1 ♀, Sept. 9. *Fort McPherson:* (T) 1 ♀, Sept. 3. *Camp Wheeler:* (T) 1 ♀, Aug. 13. *Warner Robins Air Depot:* (T) 1 ♀, Aug. 15; 1 ♀, Sept. 26. *Moody Field:* (L) 2, Aug. 26. *Camp Stewart:* (T) 17 ♀♀, Aug. 8–29; 30 ♀♀, Sept. 1–30. *Hunter Field:* (T) 10 ♀♀, 1 ♂, Aug. 8–19; 2 ♀♀, Sept. 5, 17. MISSISSIPPI—*Columbus Army Flying School:* (T) 1 ♀, Sept. 18. *Greenville Army Flying School:* (T) 1 ♀, Sept. 13; 1 ♀, Oct. 12. *Mississippi Ordnance Plant:* (T) 1 ♀, Sept. 18. *Camp Shelby:* (T) 9 ♀♀, July 12–18. *Mississippi Institute of Aeronautics:* (T) 1 ♀, July 16. *Jackson Army Air Base:* (T) 2 ♀♀, July 13, 20; 4 ♀♀, Aug. 20; 21 ♀♀, Sept. 17–22; 12 ♀♀, Oct. 1–2.

Uranotaenia sapphirina (O. S.)

NORTH CAROLINA—*Camp Sutton:* (T) 1 ♀, Sept. 10; 1 ♂, Sept. 17. *Fort Bragg:* (L) 2, Oct. 24–30. (R) 1 ♀, June 1; 1 ♀, July 4; 6 ♂♂, Oct. 14. (S) 1 ♀, July 14, 2 ♀♀, Sept. 26, 28; 4 ♀♀, Oct. 5–28. *Camp Davis:* (T) 2 ♂♂, 34 ♀♀, June 14–23; 1 ♂, 25 ♀♀, July 2–29; 13 ♂♂, 27 ♀♀, Aug. 2–31; 3 ♂♂, 12 ♀♀, Sept. 11–Oct. 2; 8 ♂♂, 13 ♀♀, Oct. 6–31; 1 ♀, Nov. 19.—3-23-43.

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Some Entomological Aspects of Troop Mobilization[1]

WILLARD V. KING, *Lieut. Colonel, Sanitary Corps, U. S. Army*

It is said that in most wars the loss of military man power from diseases has greatly exceeded the losses of men in battle. Even during the World War our losses from diseases exceeded our battle casualties. Among the most serious of these are the diseases transmitted by blood sucking insects, of which malaria, plague, typhus and yellow fever are pre-eminent. Included also are some of the intestinal infections, especially typhoid, cholera and the dysenteries, in which mechanical transmission by insects may play a highly important role under war conditions These conditions involve the mobilization and concentration of large groups of men, first in training camps and then in combat zones where sanitary problems and necessary control measures differ from those required around permanent installations in this country.

Of the four diseases referred to above, which are transmitted directly by blood sucking insects, one, yellow fever, appears to have been removed to a large extent from the list of great hazards by the development of a highly efficient vaccine. Because of the efficiency of the vaccine it might be concluded that the control of the mosquito vectors is no longer of importance. However, it would be a vast under-

[1] Prepared for a Symposium on "Entomology and The War," arranged by the American Association of Economic Entomologists and The Entomological Society of America.

taking to immunize the entire native population in troop concentration areas and combat zones and unless other precautionary measures are taken large scale epidemics among such populations might mean disaster to the campaign. Yellow fever is still widespread in Africa and the great increase in airplane transportation to eastern countries holds a constant threat of its spread to India, China and the Malayan region. Moreover, the principal vector of yellow fever, *Aedes aegypti*, also transmits dengue fever, which is widely distributed in tropical regions and to which our troops are largely non-immune. Active control of this and other potential vectors in all mobilization areas, and rigid measures to prevent transfer of infective specimens by planes and ships must be continued.

Malaria, in spite of the great advance in our knowledge of the disease and its vector mosquitoes, still remains as one of the most important hazards to which our armies will be subjected. The Medical Departments of the Army and Navy have carried out extensive malaria control programs within the camp reservations and in the preceding paper, Dr. L. L. Williams has referred to the measures that have been put into effect in the vicinity of the training camps in this country. It would therefore seem that the situation has been safely handled in our own endemic areas. In the writer's opinion one of the important outcomes of the work here has been the training of sanitary personnel and the education of the combat troops themselves in the malaria problem, which should be of benefit in foreign regions. It is apparent that our troops will be much more widely scattered in malarious areas than they were during any previous war.

In the more permanent encampments or stations, more or less effective protection can be furnished by the usual methods of malaria control, i.e., screening and destruction of the larvae and their breeding places. In temporary bivouacs and in actual combat other measures such as individual self-protection must be used. This includes the use of mosquito bars, proper clothing, repellents, head nets, and sprays; also the soldier must acquire a sense of constant vigilance.

During the last war, plague did not become a major problem and it is difficult to estimate what the possibilities are of its becoming so in the near future. It is a disease with explosive characteristics. The great disturbance of domestic life and economy brought on by war will almost certainly be accompanied by an increase in the rat population. This must be guarded against in endemic plague regions as well as in endemic areas of flea-borne typhus.

Lice constituted one of the major insect problems of the last war and were responsible for outbreaks of epidemic typhus and for serious trouble from trench fever. In addition, these insects are of real importance as destroyers of the peace of mind and morale of infested troops. A vaccine is now being used against typhus and considerable advance has been made recently in the methods of treating infested clothing and in the development of effective repellents. Since lice thrive best under conditions found in temperate and cold regions, it may be pointed out that the two groups of insects, malaria mosquitoes and lice, between them cover a large part of the habitable regions of the globe.

Regarding the intestinal infections, typhoid fever, which played such havoc during the Spanish-American war, has been largely brought under control since then by sanitation and vaccination. The bacillary dysenteries and diarrheas, however, are still one of the major problems and here the house fly comes prominently into the picture. In the opinion of some capable observers, this insect will, or may, become the most important of our sanitary problems.

In the United States, the solution of the house fly problem will, it is believed, require the concentrated action of the proper authorities both inside the Army reservations and in the adjacent areas, just as is done in the fight against malaria. Careful inspections by trained workers to locate all important sources of housefly breeding so that flies can be destroyed before they reach adult stage is the keynote in a housefly campaign. The usual measures directed against adult houseflies will have to be employed where satisfactory control of housefly breeding is not possible. Since the range of flight of this insect is considerably greater than that of the malaria mosquito, the area to be controlled is correspondingly greater. The training of personnel and the development of practical methods for the control of this pest is becoming urgent.

ARMY EMPLOYMENT OF ENTOMOLOGIST.—During the first World War a few entomologists were commissioned in the Army. They were made use of principally in the control of mosquitoes, houseflies and lice, but several were employed in laboratory studies of human intestinal parasites. At the beginning of the present war 14 entomologists held reserve commissions in the Sanitary Corps and all of these were called to active duty in the spring of 1941. With the active interest of Colonel W. A. Hardenbergh, Sn. Corps., Chief of the Sanitary Engineering Branch, Division of Preventive Medicine of the Surgeon General's Office, additional entomologists have been commissioned until at the beginning of 1943 approximately 100 are on active duty. Most of these are assigned to entomological and other sanitary work at individual camps. A number are on overseas duty and about eleven are assigned as entomologists at the Service Command Laboratories and Headquarters. In Atlanta there are three officers assigned to the Fourth Service Command Laboratory and one to the Office of the Chief of Medical Branch, Fourth Service Command. In addition, a number of graduate entomologists serving as enlisted men have received assignments in sanitary work. At our laboratory there have been eight of these. One of the eight has been commissioned and three others transferred, after a period of training, to other posts. A considerable number of selected entomologists, particularly those who have had experience on mosquito work, have also been commissioned in the Medical Department of the Navy.

The qualifications for appointment of entomologists as First Lieutenants in the Sanitary Corps include the completion of four years of college leading to a Bachelor's degree in the field of entomology from a recognized institution, and at least four years of actual experience in the field of medical entomology. An M.S. degree in Entomology may be substituted for one and one-half years of experience and a Ph.D. or equivalent degree in Medical Entomology substituted for three years of experience. Because of the lack of graduates specializing in Medical Entomology, applicants qualified in other branches of entomology have been accepted.

In both the United States and foreign regions the principal work of commissioned entomologists has been in connection with mosquito control, with particular reference to the control of anophelines. It is the function of the Medical Department of the Army to make the necessary investigations and recommendations for mosquito control while the application of the control measures is the responsibility of the Corps of Engineers. In the larger camps in the southeast both a sanitary engineer and an entomologist generally have been assiged to the Office of the Post Surgeon for this work, and this combination has been very satisfactory. The system of mosquito collections which has been put into effect in the Fourth Service Command to maintain a continuous index of mosquito densities and the efficiency of control measures has been outlined in a recent paper.[1] Other insect pests that have demanded a great deal of attention in most of the training camps are cockroaches, bedbugs and houseflies.

ENTOMOLOGICAL CONTRIBUTION TO DISEASE PREVENTION.—From what has been written above it is clear that entomologists have been given more of an opportunity than ever before to take an important part in preventive medicine and every effort should be made to do a noteworthy job. The idea still prevails in some quarters that entomologists are useful principally for the collection and identification of insects. This can be overcome by demonstrated abilities in other phases of the work. The scarcity of positions offered in the past for medical entomologists in public health work is responsible in part for the scarcity of capable men with experience in the handling of practical problems.

Among our shortcomings as practicing entomologists is the fact that our published recommendations of control measures frequently do not meet the conditions under which they are to be applied. In many cases they are based merely on laboratory results. Usually a variety of methods are given, with little information as to their relative efficiency or limitations. This has resulted in considerable criticism from those who have the responsibility of the control problems and the procurement of insecticides.

Another difficulty that is becoming more and more pressing at present is due

[1] King, Willard V. and Dwight M. Kuhns, Development of Entomological Service of the Fourth Service Command Laboratory as Applied to the Army's Mosquito Control Program. Proceedings of the National Malaria Society, 1942. In Press.

to the scarcity of certain standard insecticides, especially pyrethrum, which have been depended upon in the past. There is need for effective substitutes for pyrethrum for insect control work. Information is necessary as to whether other substances such as thiocyanates including lethane may be substituted for pyrethrum and rotenone sprays. Sodium fluoride, which is usually recommended as the best insecticide against cockroaches, is generally mistrusted for use around kitchens and pantries and for storage with food supplies. This mistrust is justified where careless personnel or those of low intelligence are involved. One ill effect of the status of these control problems is that attractive openings are offered for the introduction of patented products, the effectiveness of which is doubtful and the formulae secret.

In general, the remedy for such difficulties will require careful study and planning on the part of entomologists, the employment of more trained personnel for the handling of insect problems on the part of the Army organizations, and arrangements for adequate and uniform supplies of the proper insecticides. More intensive training of graduating or graduate students in medical entomology, with special attention given to actual practice on large scale problems, will be a valuable contribution from the entomological profession.

In conclusion, the tremendous importance in troop concentrations of certain diseases transmitted by insects, particularly malaria and dysentery, should be reemphasized. They are capable of determining the success or failure of campaigns. Since effective vaccines against these two diseases are not available, their control is largely an entomological problem and as such should be made the responsibility of entomologists. We have the opportunity and duty to develop our function in this field.—3-13-43.

A Fungous Disease of the Comstock Mealybug

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The Comstock mealybug, *Pseudococcus comstocki* Kuwana, was first found causing damage to apples in Virginia in 1934. Since that time the insect has been found in three of the apple-growing regions of the State and at times has caused severe damage to the fruit. In some instances the injury has been pronounced for one or more years, followed by a period in which the injury was extremely light and very few mealybugs present in the orchards. This paper discusses some of the environmental conditions that appeared to influence the development or the mealybug fungus and points out that during the years 1940, 1941, and 1942 the population of mealybugs was greatly reduced by the fungous disease.

DEVELOPMENT OF THE COMSTOCK MEALYBUG.—It appears that development of the Comstock mealybug through the summer season is influenced somewhat by weather conditions. A severe infestation of the mealybug in 1939 in the Roanoke and Crozet areas resulted in the deposition of a large number of wintering eggs. In the Winchester area, the number of wintering eggs was not unusually large in the infested orchards. Hatching of the eggs in all three areas was delayed somewhat by the cool weather in the spring of 1940. The season of 1940 was comparatively cool with heavy precipitation. The month of August was featured by numerous and prolonged rains in all three areas, although the total rainfall for the month was less at Winchester than at the other points. The season of 1940 seemed to retard the development of the mealybug, there being two generations and a partial third generation, with the result that fewer wintering eggs were deposited in the fall.

The summer of 1941 was sharply in contrast to that of 1940. The temperature was higher and there was a definite shortage in precipitation except in June and July. The month of May, at which time mealybug eggs were hatching, was dry and warm; and warm dry weather prevailed in late

summer and fall. In July the rains were distributed throughout the month in the Roanoke and Crozet areas but were confined largely to the first week in the Winchester area. There were three generations of the mealybug during the season of 1941. In the Roanoke and Crozet areas, the mealybug population was considerably less than in previous years. Two moderate infestations existed in parts of two orchards in the Roanoke area. In the Winchester area, the mealybug population increased in the recently infested orchards and new outbreaks occurred in two orchards.

The temperature for the summer of 1942 was warm and ample precipitation prevailed throughout the season, except during the early part of May and during the month of July. There were three generations of the mealybug during the season of 1942. In the Roanoke area the mealybug caused considerable damage to the apples in parts of two orchards. In the orchards where the injury was severe in 1940 no injury was evident in 1942 and mealybugs, although present, were difficult to find. Small areas of two orchards in the Crozet area supported heavy infestations in 1942 and the apples were severely damaged. Very few mealybugs were present in orchards which had experienced heavy infestations during previous years.

In the Roanoke and Crozet areas wintering eggs were difficult to find in the fall and winter.

During the season of 1942 the mealybug caused serious damage to the apples in three orchards which had not previously been infested in the vicinity of Winchester. The mealybug population increased in the orchards which had experienced heavy infestations in previous years and wintering eggs were quite abundant on the trees in the fall and winter.

A FUNGOUS PARASITE OF THE MEALYBUG.—Hough (1925) reported that 5 per cent of the mealybugs on catalpa trees were killed by a fungous disease. The fungus was identified as the *Isaria* stage of *Cordyceps clavulata*.

In August, 1939, a number of mealybugs were collected from catalpa that had been killed by a fungous disease. At this time no mealybugs were found killed by the fungous disease in apple orchards. Following a rainy period in August 1940 mealybugs in apple orchards at Roanoke, Crozet, and Winchester were found that had been killed by a fungous disease. (See figure 1.) Charles *et al.* (1941) succeeded in isolating and culturing the fungus and concluded that it was a new species. Harrar & McKelvey (1942) report on their experiments with the fungus and suggest the name *Endosclerotium pseudococcia* for the pathogen.

Since 1940, the question has arisen a number of times concerning the identity of the fungus, *Cordyceps clavulata*, and the fungus found attacking Comstock's mealybug on apple. In correspondence with the Bureau of Plant Industry, Division of Mycology and Plant Disease, Washington, D. C. it has been learned that the original fungous material, collected from catalpa trees in 1923 and identified as the *Isaria* stage of *Cordyceps clavulata*, is quite similar to the fungus attacking Comstock mealybug on apple. Very little information is available on the identity of the fungus and apparently the name of the pathogen has not been definitely determined.

FIG. 1.—Mealybugs killed by a fungous disease; note the black sclerotia showing through the broken integument.

DEVELOPMENT OF THE FUNGUS.—In August 1940 mealybugs in apple orchards at Roanoke, Crozet, and Winchester were found killed by a fungous disease. The disease appeared following a prolonged rainy period in August. At Roanoke and at Crozet the fungous disease killed about 50 per cent of the second brood females before they oviposited and destroyed

practically all of the young nymphs of the third brood. So many mealybugs were killed that the numbers of wintering eggs were greatly reduced. At Winchester the fungous disease did not kill as large a percentage of mealybugs as it did at Roanoke very little injury was evident on the fruit at harvest time. The weather was warm and dry in the late summer and fall and the mealybug population at Roanoke increased in parts of two orchards which had not been reported infested in previous

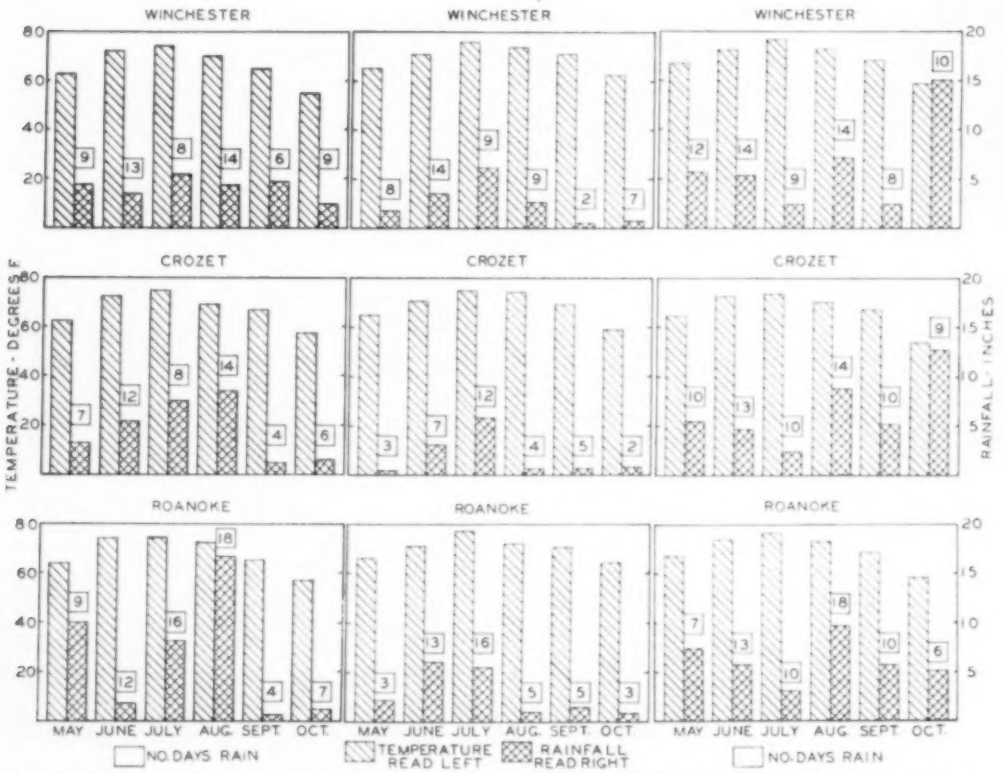

FIG. 2.—Summary of meterological data during the months in which Comstock's mealybug was active in 1940 (left), 1941 (center) and 1942 (right).

and Crozet and did not appear to be an important factor in affecting the mealybug infestation. As can be seen in figure 2 the rainfall in August at Winchester was considerably less than at Roanoke and Crozet and this probably retarded the development of the fungus in that area.

The season of 1941 was marked by a shortage of rainfall, except during the months of June and July as can be seen in figure 2. During the rainy periods of June and July the fungous disease killed about 50 per cent of the first brood of mealybugs at Roanoke and around 25 per cent at Crozet. The fungus also killed a large percentage of the nymphs of the second brood at both Roanoke and Crozet. At the end of the second brood the mealybug population was greatly reduced and years. In the vicinity of Crozet two orchards had a moderate infestation of wintering eggs in the fall of 1941.

At Winchester in 1941 no mealybugs were found that had been killed by the fungous disease. It is noteworthy, however, that the rainy periods in July occurred while most of the second generation was in the egg stage.

As is shown in figure 2 the season of 1942 was warm with considerable rain throughout the summer, except during the first part of May and during the month of July. At Roanoke a small percentage of mealybugs were killed the first part of June by a fungous disease but at this time most of the first brood females had laid their eggs and the disease did not reduce the mealybug population to any marked

extent. The month of July was warm with little rain and the second brood of mealybugs damaged the apples in infested orchards at Roanoke, Crozet, and Winchester. During the month of August considerable rain fell and the fungous disease killed about 50 per cent of the second brood females at Roanoke and Crozet before they oviposited. There was considerable rain at Roanoke and Crozet during the month of September and the fungous disease killed practically all of the young nymphs of the third brood. The mealybug population was reduced to such a degree that very few wintering eggs were found.

At Winchester during the month of August a small percentage of mealybugs were found killed by the fungous disease but the number killed did not appear to affect the infestation to any marked extent. The fungus was not observed attacking the third brood of mealybugs in September. As will be seen in figure 4 the rainfall at Winchester in September was considerably less than at Roanoke or Crozet and this may have retarded the development of the fungus. In the vicinity of Winchester damage to the apples occurred in four orchards not reported infested in previous years and the infestation in all of the orchards infested in previous years was more severe than usual.

SUMMARY.—In 1940 the Comstock mealybug severely damaged the apples in orchards at Roanoke, Crozet, and Winchester. In 1941 there was little injury to apples from mealybugs at Roanoke and Crozet but at Winchester the injury was quite pronounced. In 1942 at Roanoke and at Crozet apples in newly infested orchards were damaged by the mealybug but in orchards infested in previous years the injury was negligible and mealybugs were hard to find on the trees. At Winchester newly infested orchards suffered damage and the infestation was heavier than usual in orchards infested in previous years.

Following a rainy period in August 1940, a fungous disease killed from 40 to 50 per cent of the mealybugs in infested orchards at Roanoke and at Crozet, but at Winchester the fungus did not destroy a large number of mealybugs. In 1941 the fungus attacked the mealybugs in infested orchards at Roanoke and at Crozet but was not found attacking mealybugs at Winchester.

During the summer of 1942 the fungous disease destroyed about 50 per cent of the second brood of mealybugs and practically all of the third brood at Roanoke and at Crozet. At Winchester the fungus attacked the second brood of mealybugs in late August but the mealybugs killed by the fungous disease did not appear to reduce the infestation to any great extent. No third brood nymphs were found killed by the fungous disease.

In the fall of 1942 the mealybug population was extremely low at Roanoke and at Crozet. It is believed that the reduction in the infestation was mainly due to the attack of the fungous disease. At Winchester where the fungous disease did not destroy a large percentage of mealybugs the infestation in 1942 was more severe than usual in all infested orchards.

Environmental conditions, favorable for the development of the fungous disease of the Comstock mealybug in apple orchards, are a warm, humid atmosphere lasting for several days and a heavy infestation of the insect.—2-26-43.

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The Commissioner of Agriculture of the State of Texas revised the pink bollworm quarantine proclamation (No. 67) to clarify the requirements and rearrange the subject matter through inclusion in the regulations requirements issued subsequent to the previous revision.

Reduction of Flea Beetle Injury to Tomato Transplants by Treatment Prior to Setting

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Early in 1942 a project was begun at Cornell University to investigate the possibility of pre-setting treatment as a means of preventing, or at least reducing, the amount of injury to tomato sets by the potato flea beetle, *Epitrix cucumeris* (Harr.). Some of the results of the one year's investigations are herein reported at an earlier date than usual in the hope they might contribute, if even slightly, to the effort to use more efficiently, or to find substitutes for, those insecticides which are at present not plentiful.

As a general rule, to nato plants which are set previous to the appearance of large numbers of flea beetles become sufficiently well established to withstand the attack, and those set after the peak of emergence are also likely to escape serious injury. Fortunately, young plants frequently survive what appears to be a rather serious attack of flea beetles when one considers the number of feeding punctures in the leaflets. However, the period which does seem critical is that of the few days immediately after field setting during which the young plants are becoming firmly established. When this period coincides with the peak of flea beetle emergence injury is often so severe as to necessitate spraying or dusting. Either of these practices at this time is both costly and wasteful from the standpoints of labor and efficient use of insecticides. Obviously, considerable saving in both of these important items can be effected if it is possible to treat the plants *en masse* before transplanting.

The idea of pre-setting treatment is by no means new. Stear (1918) recommended dipping the tops of transplants in a solution of 1 pound of lead arsenate in 8–10 gallons of water. However, Turner (1940) did not obtain satisfactory protection with either lead arsenate (1–10) or barium fluosilicate (1–20) used in this manner. The technique employed for treatment in the present investigations was slightly different as can be seen from the following description:

PROCEDURE.—For the first of two experiments conducted in 1942 seed of the variety John Baer were treated with *Spergon* and planted in greenhouse flats on April 15th. The resulting plants were thinned to stand about 2½ inches apart when they had attained a height of 2 inches, and on May 20th the flats were set on a rack outside the greenhouse to afford a chance for the plants to "harden off." On May 24th all plants, except those to be used as checks, were treated. Dusting was accomplished by means of a small rubber bulb duster of the type commonly used to dust pet animals, the dusts being applied from three sides to insure complete coverage. Spraying was accomplished by means of a 1-quart fly-gun type of sprayer, the sprays being applied from three sides to the point of run-off. Individual plants were set out in a 20×20 Latin square on the day following treatment, and three days after setting the three terminal leaflets of the most obviously injured leaf of each plant were collected and spread between pages of a catalogue for later counting of flea beetle feeding puentures. As fruit ripened records were made of number, weight, and date for each plant.

In the second experiment the general procedure was the same as in the first. However, in this test the seed were planted May 26th, plants were thinned June 15th, hardened from June 27th to July 1st, treated July 1st, and set out on July 2nd. Fifteen treatments were employed, including checks, and the collection of leaflets for puncture counting was delayed until July 16th or 14 days after setting. In this test no yield records were taken.

RESULTS AND DISCUSSION.—The counts of first brood flea beetle punctures and total weights of tomatoes on the plants set in late May are recorded in table 1. Second brood flea beetle punctures on the plants set in early July are given in table 2. A study of the two tables and of field notes makes possible several interesting observations:

1. The effectiveness of the insecticides used was not reflected in terms of yields. This may have been due to the presence of

an insufficient number of flea beetles to cause severe damage. However, it is felt that the more plausible explanation is merely that other factors influencing the growth of the plants between time of setting and harvest were of more direct importance to yields than was the flea beetle population. Such is probably the usual case unless the population of insects is sufficiently large to kill some of the young plants.

2. Since some reductions in flea beetle punctures were obtained with almost all materials tested, and since very large reductions were obtained with some, it is obvious that treatment with these materials would be a sound economic procedure where flea beetles are likely to be so numerous as to otherwise warrant post-setting treatment. Expense involved is so low as to justify the pre-setting treatment even if in an occasional year the outbreak

Table 1.—First brood flea beetle punctures and total weight of tomatoes on plants treated with dusts and sprays before setting.

TREATMENT	AVERAGE PUNCTURES[1]	POUNDS TOMATOES PER PLANT[2]	RANK IN YIELDS
Levesol dust (70–75% sodium fluosilicate)	13	3.6[3]	20th
Derris-talc dust (1% rotenone)	19	11.3	11th
Calcium arsenate spray (6–100)	22	12.7[3]	6th
Volck oil emulsion spray (1–100)	24	10.5[3]	17th
Sodium fluosilicate-talc dust (50–50)	30	10.0[4]	18th
Bordeaux (4–2–50) plus *Volck* (1:100) spray	36	11.4	9th
Bancroft clay spray (4–100)	38	11.2	12th
Alorco cryolite dust (sodium fluoaluminate)	40	9.6[5]	19th
Copper oxychloride sulfate spray (3–100)	54	11.4	10th
NNOR (1:400) plus calcium arsenate (2–100) spray	56	10.9	15th
Derris spray (4 lbs. of 4% rotenone/100 gals.)	64	14.6	1st
NNOR spray (1:400)	68	13.5	2nd
Bordeaux (4–2–50) spray	70	12.8	5th
Bordeaux (4–2–50) plus calcium arsenate (6–100) spray	72	11.2	13th
Syntone spray (1:200)	96	11.1	14th
Bancroft clay-lime spray (2–2–100)	100	13.3	4th
Check (untreated)	104	13.3	3rd
Yellow Cuprocide spray (1–100)	124	10.6	16th
Lime spray (4–100)	162	12.4[5]	7th
Black Leaf 155 spray (3–100)	292	11.6	8th
Diff. for Signif. (odds 19:1)	30	2.4	
(odds 99:1)	40	3.2	

[1] Based on counts of punctures on three terminal leaflets of most obviously injured leaf of each of the 20 replicates.
[2] Average for all 20 replicates.
[3] Average of 10 plants,—others killed by treatment.
[4] Average of 16 plants,—others killed by treatment.
[5] Average of 19 plants.

of flea beetles is so severe as to necessitate a later application in the field.

3. Among all of the sprays and dusts used only those containing fluorine caused any observable plant injury. *Levesol*, containing 70 per cent sodium fluosilicate, very severely injured all plants to which it was applied,—this to the extent of killing half of them. The 50–50 mixture of sodium fluosilicate and talc severely injured 16 out of the 20 plants treated, 4 of these to the extent of death. On the other hand, the *Alorco* cryolite (sodium fluoaluminate), while slightly injuring 12 out of 20 plants treated, killed only one. This same material when mixed 50–50 with talc for use against the second brood of flea beetles produced no observable injury. In the first experiment, while no attempt is made to analyze the other factors influencing yields, it was very obvious in the field that even the surviving plants treated with sodium fluosilicate were so retarded they did not have a chance to produce maximum yields. The inference to be drawn is that of the two fluorine compounds the fluoaluminate is apparently the safer on young tomato plants and that this material should be considerably diluted.

Table 2.—Second brood flea beetle punctures on plants treated with dusts and sprays before setting.

TREATMENT	AVERAGE PUNCTURES[1]
NNOR (1:400) plus calcium arsenate (2–100 spray)	23
NNOR (1:400) spray	59
Volck oil emulsion spray (1:100)	89
Bordeaux (4–2–50) spray	93
Bancroft clay-lime (2–2–100) spray	101
Lethane-rotenone (2% *Lethane 60* plus 0.4% rotenone) dust	119
Lime (4–100) spray	123
Bordeaux (4–2–50) plus *Volck* (1:100) spray	126
Bordeaux (4–2–50) plus calcium arsenate (10–100) spray	126
Calcium arsenate (6–100) spray	143
Alorco cryolite-talc (50–50) dust	143
Bancroft clay (4–100) spray	144
Derris-talc (1% rotenone) dust	151
Derris (4 lbs. of 4% rotenone/100 gals.) spray	152
Check (untreated)	339
Diff. for Signif. (odds 19:1)	74
(odds 99:1)	101

[1] Based on counts of punctures on three terminal leaflets of most obviously injured leaf of each of the 15 replicates.

4. The difference in effectiveness of rotenone sprays and dusts in the two experiments was very marked. In the first

one, in which counts were taken 3 days after setting, the derris dust and suspension both gave satisfactory results. However, in the second test, in which counts were not taken for 14 days, these two were the poorest of the 14 materials used. That such a discrepancy was due to the exposure factor was indicated by the fact that *NNOR* gave the best results in the longer test.

5. Undoubtedly some of the effectiveness of materials as listed in the two tables is only apparent and would not prove real under conditions in which the insects had no choice of type of treated plant on which to feed. It is readily conceivable that in this type of work differences between treatments or differences between treated and untreated plants may be somewhat magnified by repellent action of some of the materials under trial. However, it must also be borne in mind that, as evidenced by the yield data, young tomato plants can be rather badly punctured and still not be short on yield at the end of the season. Hence, efficiency of insecticide in the type of treatment here suggested is only necessary to the extent of reducing the number of punctures below that which is fatal to the plant.

SUMMARY.—Results are reported for two experiments involving the use of 19 and 14 pre-setting treatments applied to tomato transplants in an effort to reduce injury by the potato flea beetle. Treatments were applied before the plants were removed from flats for field setting. Nearly all dusts and sprays used gave significant reductions in numbers of punctures although relative efficiencies were not reflected in yields. This type of treatment is therefore not suggested as a general practice. However, particularly in view of its cheapness, it may well prove to be good insurance for tomato plants to be set in those areas or during those periods in which flea beetles are extremely abundant. —2-3-43.

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Flight Habits of Carrot Rust Flies Suggest Possible Method of Control

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The possibility that the carrot rust fly, *Psila rosae* (F.), cannot thrive in windswept or exposed areas was suggested by Caesar (1927). He also thought the flight range of the species was probably rather limited, so that injury to field crops which are moved from field to field is avoided while unrotated garden crops suffer from repeated high infestations. Baker *et al.* (1942) observed the tendency of the flies to seek shelter at night, during the middle part of the day, and during windy weather. Because of the "assembling" habits of the adults these authors suggested the possibility of reducing the potential size of the second brood by spraying the hedges around fields in the early morning or late evening to kill the flies from overwintering puparia before they have had an opportunity to become generally dispersed. Petherbridge *et al.* (1942) reported good results with a bait spray of cane molasses and sodium fluoride applied to the surroundings of carrot fields as a control measure for the second brood of flies. The average infestation in untreated fields was from 133 per cent to 217 per cent higher than in fields the surroundings of which had been so treated. Results obtained in experiments conducted on the muckland in Wayne County, New York during the past two summers confirm the findings of the English workers although the approach to the problem was somewhat different.

In visiting plots of celery and carrots used primarily for testing insecticides it was repeatedly noticed that there was a great variation in the numbers of flies which could be seen at different times. To determine whether the variation might be

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associated with wind velocity, 18 plots of one square yard each were marked off in a celery field in 1941. The number of flies which could be seen in each plot were recorded throughout an afternoon, six observations being made in each plot. During the afternoon the temperature dropped only two degrees, from 67° to 65° F. No anemometer was available to record actual wind velocities so, to obtain a relative value, a light, fluffy ball of cotton 1.5 inches in diameter was dropped five times from eye level and the average distance in feet to which it was blown was recorded. This was done each time a set of fly counts was made. Relative wind velocities and results of the fly counts are shown in table 1. The total number of flies to be seen increased markedly with decrease in wind velocity although some variations occurred in the actual counts. Examination of the counts in the individual plots revealed a slight indication of a regular progressive movement of the flies into the small portion of the field surveyed.

When flies of the overwintering generation became abundant in 1942 observations on flight habits were renewed although not in definite plots. A celery field was selected which was bordered on one side by a patch of woods, largely elms and maples, and on the other by a ditch. Observations were made on the whereabouts of flies from 1:00 p.m. until dark. In the early afternoon no flies could be found in the field. As the afternoon breeze died down, and also as the sunlight became less bright, a few flies were first found in the lee of the ditch, then they became

Table 1.—Variation in numbers of carrot rust flies with decreasing wind velocities.

TIME OF OVSERVATION	RELATIVE WIND VELOCITY	NUMBER OF FLIES OBSERVED
3:00 p.m.	15[1]	8
3:30	11	14
4:00	10	30
4:40	8	28
5:30	7	48
6:15	4	23

[1] Distance in feet to which 1½ inch cotton ball was blown when dropped from eye level.

numerous along the ditch, and between 6:30 and 8:00 o'clock they spread out rapidly over the field. Between 8:00 and 9:00 the temperature in the field dropped about 8 degrees, and just before dark the flies were hard to find. Therefore, no definite mass movement was detected, but two individuals which were followed as closely as possible during the hour were seen to rise rapidly from the celery and fly off toward the woods.

When flies of the first generation became abundant in August of 1942 three locations were selected to determine the relative numbers of flies in darkly shaded and lightly shaded areas. Each location consisted of a spot in which a tree partly shaded a celery field. The celery was between 12 and 18 inches in height and its growth was sufficiently dense to afford at

Table 2.—Average number of flies per 5 sweeps in darkly and lightly shaded areas of 3 locations.

LOCATION	NUMBER OF FLIES IN	
	Dark Shade	Light Shade
1	4.75	1.25
2	45.75	1.37
3	11.00	1.33

least light shade without aid from the trees. The spots immediately under the trees were therefore rather darkly shaded. Various numbers of sweeps were made at the three locations, but in table 2 the counts of flies have been reduced to a five sweep basis. They show rather conclusively that the flies prefer the darkest shade available. Further support to this theory is given by the fact that after sundown the counts in the same areas of location No. 2 as shown in the table changed to 5.00 and 2.62 flies per five sweeps respectively. It was apparent that the flies which had congregated in the dark shade during the afternoon had again become dispersed.

While rearing technique for carrot rust flies was being studied in the greenhouse during the winter of 1941–42, what appeared to be feeding of adults was observed on the surfaces of carrot leaves (more on the wet surfaces than dry), on honey-dew from aphids infesting the carrots, and on droplets of water left on the aster-cloth walls of the cages when the plants were watered. Such activity suggested the possibility of killing adults in the field by using poison sprays where they congregate. One such place appeared to be the edge of woods adjacent to celery or carrot fields. So, on May 27th, 1942, a young maple tree at the edge of an in-

fested celery field was sprayed with two gallons of calcium arsenate and water (5–100). An aster-cloth net was spread under the tree covering a radius of 6 feet from the trunk. Numbers of dead flies found in the net were recorded daily, and a total of 74 were collected in 13 days. The tree was again sprayed on June 9th, and on the 7 following days an additional 26 dead flies were found in the net. Thus, in 20 days 100 dead flies were collected. Some of the mortality may have been from natural causes, but the probability that most of it was the result of poisoning was indicated by results obtained in another brief test. In this case 3 cellophane cages were placed over sprayed maple branches and 3 over unsprayed branches. Into the six cages 26 flies were introduced, and counts of dead and living flies made two days later in the two series revealed an 80 per cent mortality among the flies confined on sprayed branches as against none among those on unsprayed branches.

No attempt was made to secure control of the carrot rust fly by spraying all of the ditches, brush, etc., around a field of carrots or celery. However, a calcium arsenate-*Pyrax* (20–80) dust was applied to carrot plots on three farms after first generation adults began to emerge on July 29th. On one farm no infestation developed, on another no reduction in wormy carrots was obtained, and on the third a reduction from 36 per cent to 26 per cent wormy resulted from the treatment. This failure to obtain control is easily explained by the fact that extensive migration back and forth between the borders and centers of the fields took place even when the top growth was rank. Due to constant influx of unpoisoned flies and the probability that many of them lay eggs before being poisoned, small field plots are not suited to the measurement of kill obtained by the application of poisons. This was strongly indicated some years ago by Glasgow & Gaines (1929), who made 4 to 6 applications of arsenical sprays, beginning when the first flies emerged, but failed to obtain consistently satisfactory results. These workers suggested that the failures might be due to the short feeding period between emergence and oviposition, or to migration of flies into their plots.

Injury from the first generation larvae can be avoided by delaying planting until flies from overwintered pupae are out and have started ovipositing. Such practice avoids furnishing attractive plants for oviposition and thus concentrates the flies around wild hosts. Poisons applied to the edges and surroundings of the field at this time might easily prove most effective in killing the adults and thereby lessen the potential size of the second generation. Whenever it is possible to do so it would probably be wise to (1) use an open field as far removed as possible from the field used the previous year, (2) apply poisons to the surroundings of the previous year's field during emergence of the first brood of flies, from approximately May 25th to June 15th in western New York, (3) plant the current year's crop about June 1st or sufficiently late to avoid first brood injury, and (4) treat the shelter surrounding the current year's crop during late July and August to kill flies emerging during these months. Such a program would obviously not kill all flies but should reduce injury to a minimum.—3-26-43.

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The Relative Abundance of Cabbage Caterpillars on Cole Crops Grown under Similar Conditions[1]

P. K. Harrison and Ross W. Brubaker,[2] *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[3]

During the course of studies on the control of the imported cabbage worm, *Pieris rapae* (L.), the cabbage looper, *Autographa brassicae* (Riley), and the larvae of the diamondback moth, *Plutella maculipennis* (Curt.), observations indicated that some types of cole crops are more attractive to these cabbage caterpillars than are others, and that red or purple varieties of cabbage are not so susceptible as the green varieties. In order to obtain some experimental data on the subject, studies were carried on and experiments were conducted at Baton Rouge, La., each fall during the period 1939–41, inclusive. Seven different types of *Brassica* were used, with the addition of red or purple cabbage.

Methods.—Eight plots, 25 feet long and 8 feet wide and containing two rows,

[1] In cooperation with the Louisiana Agricultural Experiment Station.

[2] Now in active service in the U. S. Navy.

[3] Thanks are due C. E. Smith for his advice and cooperation in this work, and to Davidson B. Lieux and Floyd M. Mizell for their assistance in obtaining the field data.

Table 1.—The numbers of cabbage caterpillars and pupae found per 100 plants on 8 different *Brassicae* in 3 field experiments, Baton Rouge, La., 1939–41.

Host Plant	Loopers	Imported Cabbage Worm	Larvae of Diamondback Moth	Other Species	All Species
		FALL 1939 EXPERIMENT			
Broccoli	174	245	16	19	454
Cauliflower	184	208	18	13	423
Collards	181	151	29	16	377
Brussels sprouts	178	162	16	18	374
Red cabbage	197	86	12	5	300
Green cabbage	148	42	24	4	218
Kohlrabi	76	83	9	2	170
Kale	90	46	8	5	149
Average	154	128	17	10	308
Difference required for significance when P=.05	20	41	4	12	54
Difference required for significance when P=.01	27	55	5	15	72
		FALL 1940 EXPERIMENT			
Collards	515	64	16	1	596
Red cabbage	423	34	6	1	464
Broccoli	323	64	6	2	395
Cauliflower	292	53	9	4	358
Brussels sprouts	300	26	8	1	335
Kale	218	14	3	1	236
Green cabbage	208	22	4	1	235
Kohlrabi	190	27	5	2	224
Average	307	38	7	2	355
Difference required for significance when P=.05	56	10	3	1	58
Difference required for significance when P=.01	75	13	4	1	78
		FALL 1941 EXPERIMENT			
Broccoli	67	132	14	19	232
Collards	83	104	19	15	221
Red cabbage	85	54	16	6	161
Green cabbage	54	53	18	9	134
Cauliflower	38	70	13	7	128
Kohlrabi	30	51	10	3	94
Kale	41	32	8	6	87
Brussels sprouts	23	35	6	10	74
Average	53	66	13	9	141
Difference required for significance when P=.05	20	18	5	11	37
Difference required for significance when P=.01	28	23	6	14	49

were planted to each of the following kinds of plants: Green cabbage, red cabbage, collards, cauliflower, kale, broccoli, brussels sprouts, and kohlrabi. The 64 plots in the experiment were arranged in a Latin square. To insure a stand of plants and that the plants would be in condition to attract the adult insects during the period of observation, the plantings were protected during the early stage of growth by

RESULTS.—In the 1939 experiment 11 caterpillar-infestation counts were made, the first on September 14–15 and the last on November 27–28. Three of these counts were made in September, 4 in October, and 4 in November. The first caterpillar-infestation count in the 1940 experiment was made on September 25–27 and the last, or tenth count, on November 26–27, as follows: 1 count in September, 5

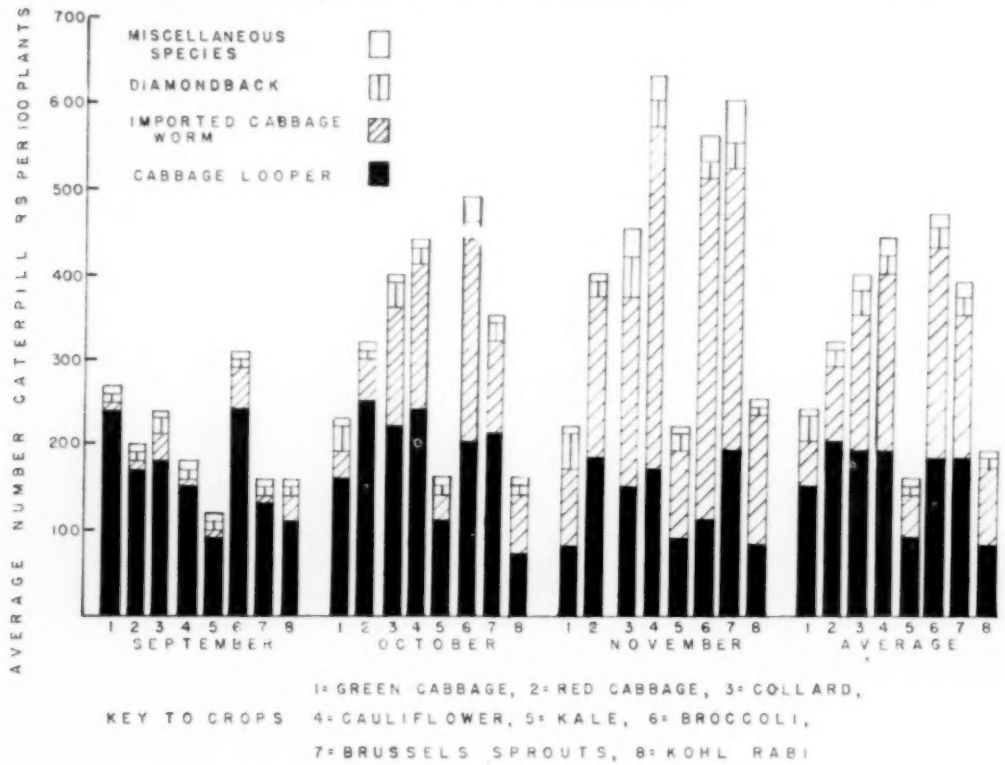

FIG. 1.—Comparison of the caterpillar populations by crops, species, and months, and the averages for the 3-month period in host-preference experiment, Baton Rouge, La., 1939. (Vertical scale indicates caterpillars per 100 plants, average). Key to Crops: 1. Green cabbage; 2. Red cabbage; 3. Collards; 4. Cauliflower; 5. Kale; 6. Broccoli; 7. Brussels sprouts; 8. Kohlrabi.

making 2 applications of a cryolite-talc (3–1) dust mixture in 1939 and 1941 and 4 applications of a calcium arsenate-paris green (10–1) dust mixture in 1940. The application of these dust mixtures was discontinued in time to avoid interference with the subsequent caterpillar-population studies. Twenty plants per plot were examined at weekly intervals and the number of larvae and pupae present were recorded by species. An attempt was made to grow the kohlrabi plants 9 inches apart in the row and all the other plants 18 inches apart.

in October, and 4 in November. In the 1941 experiment 11 counts were made, the first on September 30 and the last on December 9 to 12, as follows: 1 count in September, 4 in October, 4 in November, and 2 in December.

The average number of caterpillars per 100 plants of those species present in numbers sufficient for comparative study for the three experiments, arranged by crops and by caterpillar species, and the numbers required for significant differences between crops are presented in table 1. Comparisons of the caterpillar popula-

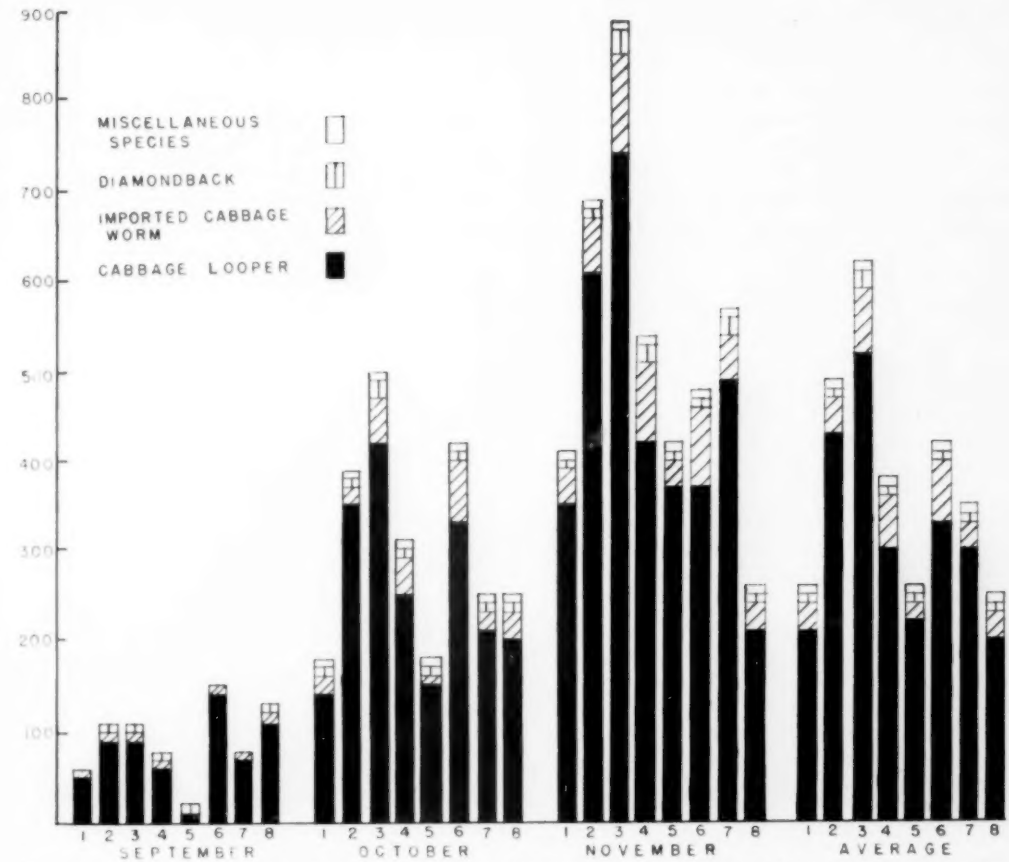

FIG. 2.—Comparison of the caterpillar population by crops, species, and months, and the averages for the 3-month period in host-preference experiment, Baton Rouge, La., 1940. (Vertical scale indicates caterpillars per 100 plants, average). Key to Crops: 1. Green cabbage; 2. Red c bage; 3. Collards; 4. Cauliflower; 5. Kale; 6. Broccoli; 7. Brussels sprouts; 8. Kohlrabi.

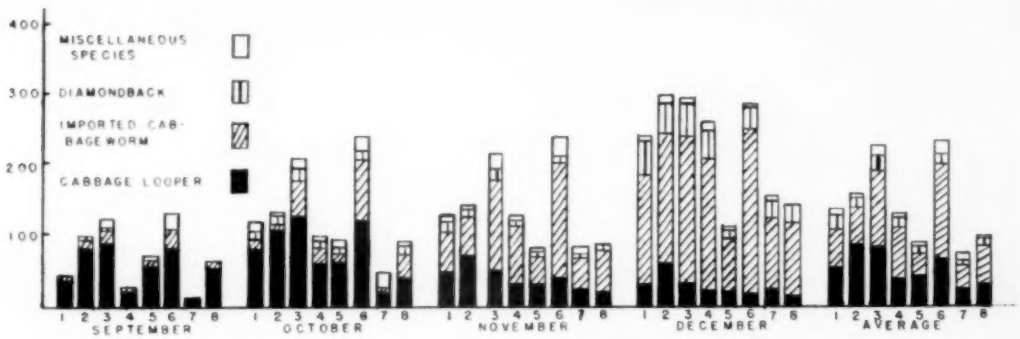

FIG. 3.—Comparison of the caterpillar population by crops, species, and months, and the averages for the 4-month period in host-preference experiment, Baton Rouge, La., 1941. (Vertical scale indicates caterpillars per 100 plants, average). Key to Crops: 1. Green cabbage; 2. Red cabbage; 3. Collards; 4. Cauliflower; 5. Kale; 6. Broccoli; 7. Brussels sprouts; 8. Kohlrabi.

tions by crops and by species for each month and for the entire period of each experiment are illustrated in figures 1, 2, and 3.

DISCUSSION OF RESULTS.—There were significant differences between the numbers of caterpillars on some of the crops, as is shown in table 1. As is also shown in

table 1 and figures 1, 2, and 3, the total population and the relative abundance of the different caterpillar species varied considerably on the different plants and during the different seasons. The cabbage looper was more abundant on 5 of the 8 types in 1939, on all 8 types in 1940, but on only 3 of the 8 types in 1941. The imported cabbage worm was the most abundant species only in 1941 and ranked second in 1939 and 1940. Although green cabbage in the 1939 experiment was among the types supporting the heaviest population during September and to about October 20, the population on green cabbage decreased considerably thereafter, in comparison with the population on some of the other types. Early maturity of the green cabbage, which began about the middle of October, may have made them less attractive to the adult female insects for egg laying. On the other hand, at that time some of the other types were just reaching the stage of growth which seemed to be most attractive for egg deposition, namely, that comparable to cabbage just beginning to head.

Although the caterpillar populations were much smaller in the 1941 experiment, the average trend of the number of caterpillars was similar to that in the other two experiments. In all three experiments red cabbage supported larger total populations than did the green cabbage—in fact, almost twice that of green cabbage in the 1940 experiment.

Broccoli supported the largest total population in 1939 and 1941, whereas collards supported the largest total population in 1940. Kale supported the smallest total population in 1939, kohlrabi in 1940, and brussels sprouts in 1941. In the 1941 experiment the brussels sprouts plants were small and in poor condition on account of adverse weather conditions, which probably accounted for the low population on this type in that year. Since the kohlrabi plants were 9 inches apart, whereas the others were 18 inches apart, the populations given in table 1 can be expressed as caterpillars per 150 row feet by doubling the entries for kohlrabi. On this basis of comparison the latter supported the third from the largest number of caterpillars in 1940 and 1941, and the fifth from the largest number in 1939.

The variation in the number of caterpillars supported by any one of the 8 types of plants is believed to be due largely to the relative amount of foliage produced by the plants, the stage of plant maturity, the height of the plants, and their general physical condition. It is therefore evident that in these experiments the relative abundance of caterpillars did not indicate accurately the host preference. The experiments are of value, however, in that no outstanding resistance to cabbage caterpillars was shown by the red cabbage or any of the other tyes of *Brassica* tested.

SUMMARY.—Studies were begun in 1939 and continued through 1941 to determine the relative abundance of the cabbage looper, the imported cabbage worm, and the larva of the diamondback moth on certain of the different types of cole crops. Three experiments were conducted in which green cabbage, red cabbage, collards, cauliflower, kale, broccoli, brussels sprouts, and kohlrabi were used.

The number and species of caterpillars and pupae on 20 plants per plot were recorded at weekly intervals. In all three experiments red cabbage was more heavily infested with caterpillars than was the green cabbage. Broccoli and collards supported the largest total populations.

General observations indicated that the number of caterpillars supported by the plants was largely due to factors other than the type of *Brassica*, and consequently that the relative abundance of the caterpillars does not indicate accurately the host preference. It is noteworthy, however, that no outstanding resistance to cabbage caterpillars was shown by any of the types of *Brassica* employed in the tests reported.—2-9-43.

ENTOMA FOR 1943 APPEARS

Entomologists and other users of *Entoma* will welcome the fifth edition which has recently been mailed to the members of the Association. Dr. Hamilton and his associates are to be congratulated on the quality and appearance of the new edition. The journal will publish a more adequate appreciation of the work in a later issue.

Factors Affecting the Rotenone Content of Devil's Shoestring[1]

A. F. Sievers, M. S. Lowman and G. A. Russell[2]

In the world-wide search for efficient insecticides of plant origin which are non-toxic to man and animals, the devil's shoestring, *Tephrosia virginiana* (L.) Pers. is deserving of serious consideration. Since the report by Little (1931) that the roots of this native legume possess insecticidal properties and the finding by Clark (*1933*) that they contain rotenone, interest in the commercial possibilities of the plant has continued. Its culture would fit well into the agriculture of the southern and southeastern sections of this country where it grows sometimes in considerable abundance on the poorer types of soil to which it is well adapted. In a survey of the plant's distribution and its relative insecticidal value throughout its principal range, Sievers and co-workers (*1938*) showed that the plant in its wild state contains no rotenone or only traces except in a few restricted localities in southwest Georgia, northeast Florida and in a number of areas in Texas, some extending into Louisiana and Oklahoma. The most important area, where the plants have shown the highest toxicity comprises a rather narrow belt of Norfolk sand in Texas, extending about 300 miles from Luling in Caldwell County northeasterly to Marshall in Harrison County. The survey sought to determine whether the presence or quantity of rotenone in the roots is a result of environment or is a genetic character and to ascertain if any botanical characteristics of the plant are associated with rotenone content. No such relationships could be found. Some evidence of the influence of environment was noted in some localities but no general theory on this point was possible from the observations made. Data were obtained suggesting that the capacity of some plants to produce rotenone to greater degree than others is a genetic character but that such character is subject to modification by environment.

[1] The authors acknowledge the helpful cooperation of Otis Woodard, Georgia Coastal Plain Experiment Station, Tifton, Ga., and L. E. Scott, Sandhill Experiment Station, Columbia, S. C.

[2] Senior Biochemist, Associate Biochemist and Agent, respectively, Division of Drug and Related Plants, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, in cooperation with the Texas Agricultural Experiment Station. Technical Series No. 781. Texas Agricultural Experiment Station.

Little (*1942*) in a recent publication reported on the effects on the rotenone content of transferring the plant in Texas from Norfolk sand to clay. He states in conclusion "it has been shown that highly toxic plants retain their toxicity when transferred to a region yielding only mediocre material and also that they remain toxic when transferred from one soil to another." While his results are clearly conclusive with respect to the particular localities in Texas involved they cannot be assumed to demonstrate that planting stock of plants of desired toxicity may be transferred to any region where the plant will grow with the certainty that the toxicity of the plants thus grown will be at least high enough to make them commercially useful. However, it is indicated by the experiments in New Jersey, reported recently by Ginsberg, *et al.* (*1942*), that planting stock of toxic plants from one region may be transferred to other regions far removed without loss of quality of the roots produced in the new environment. It was found that native plants in nine localities in the State contained practically no rotenone and possessed very little toxicity but that those from plants grown from seed obtained from Texas contained from 0.76 to 1.4 per cent rotenone.

Before this plant can be introduced as a commercial crop in widely separated regions it is of course necessary to know whether is must be restricted to certain selected localities or whether proper strains of the species may be grown in any desirable region without preliminary trial plantings to determine if the roots thus obtained will have the necessary rotenone content. In the course of the survey the maximum content found was about 1.5 per cent but in a later study when a more intensive search was made in the northeast Texas region mentioned, plants with substantially more rotenone were found, which since then have been used for further selection and for breeding purposes. While a few individual plants of strains containing 5 and 6 per cent of rotenone are now on hand all the the various field experiments on culture, harvesting, etc., are being conducted with stock,

the rotenone content of which ranges from 0.5 to 3.0 per cent.

METHODS.—Experiments were undertaken to obtain the information on this subject necessary to determine whether the quality of planting stock or the influence of environment is the dominant factor that must be considered in introducing devil's shoestring as a commercial crop in regions remote from those in which the wild plants generally contain rotenone. These involved some preliminary tests on seedlings followed by regional plantings of crown divisions from plants of known quality to note the effect of environment on the rotenone content. Although the results are not entirely conclusive they are presented here because they are believed to be of help in planning any commercial introduction.

Seed was collected from plants growing wild in three regions where the usual quality of such plants had been determined previously by means of the Durham test (Jones & Smith 1933). These regions were: (1) near Ingram, Va., where no plants containing more than a trace of rotenone could be found; (2) in northeast Texas where most of the plants contain some rotenone and some of them as high as several percent; (3) near Cordell, Ga., where most of the plants tested contained rotenone in limited amounts. Seedlings grown from these three lots of seed in the greenhouse were planted in the spring of 1935 in a bed at Arlington, Va. In this general locality no wild growing plants have been found that give a positive test for rotenone. In the fall the plants were only large enough to remove a few pieces of roots for testing with the Durham color test. A year later certain individual plants of each lot were staked and enough root material collected to permit a quantitative extraction with acetone for the Durham test. The same procedure was followed in the fall of 1937 in connection with most of the same individual plants. The results of these tests are summarized in table 1.

As would be expected, the plants grown from the seed from Ingram, Va., gave negative results. It is significant, however, that those among the plants derived from Texas and Georiga seed that gave a positive test the first year remained so in a general way. Certainly it is obvious in this case that growing in a region where toxic plants apparently never occur in the wild state or at least have never been found, did not cause the plants to lose the limited rotenone content they possessed at the start. This is especialy significant because the observations extended over three growing seasons. Some of the plants grown from seed from Georgia actually improved from year to year.

Table 1.—Number of individual plants of devil's shoestring grown at Arlington, Va., from seed obtained from three regions, which gave various degrees of color with the Durham test.[1]

SOURCE OF SEED	1935					1936					1937				
	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e
Virginia	12	0	1	0	0	13	0	0	0	0	12	0	0	0	0
Texas	3	0	0	5	3	5	3	4	7	0	4	6	2	4	2
Georgia	2	0	0	4	4	1	0	2	5	5	1	0	2	7	3

[1] The degree of blue color obtained is roughly indicative of the amount of rotenone present. (a) = no color; (b) = trace; (c) = pale blue; (d) = blue; (e) = deep blue or darker. Generally, with the concentration used here, the roots that give less than a deep blue color usually possess no measurable rotenone content or significant insecticidal value.

STUDIES ON CROWN DIVISIONS.—In the spring of 1938 ten plants which contained rotenone in a varying degree were taken from the experimental plot at Milano, Texas, which is in a region where most of the plants growing wild contain rotenone. The crowns were divided in two pieces leaving sufficient roots on each to assure good growth. One portion was immediately replanted there and the other sent to Arlington, Va., for planting. Thus, crown divisions from the same parent plants would be growing in two localities, one in a region where most of the wild plants contain some rotenone and the other where they almost invariably do not contain any. Enough root material was removed from the divisions received at Arlington, Va., to make the Durham test and in six of the ten there was sufficient to determine the rotenone content. These

plants were allowed to grow undisturbed during the 1938 season and were dug in 1939, those in Virginia about the middle of July when the seed pods were developing, and those in Texas on August 12, at a somewhat more advanced stage of growth. The roots were removed, cleaned, dried, and the percentages of rotenone and chloroform extract determined. The results are assembled in table 2.

Obviously the environment at Arlington, Va., did not prevent the production of rotenone by the plants as shown by the rotenone content of the roots after two seasons' growth. In fact, in eight of the nine plants in comparison the percentage was higher in those grown in Virginia. In an earlier investigation (Sievers *et al.* 1940) it was found that the rotenone content is highest when the plant is in full bloom. Inasmuch as the Virginia plants were taken up when they were more nearly at this stage than the Texas plants on August 12, the somewhat higher rotenone content of the former may be due in part to that. The low rotenone and chloroform extract content of the progeny by crown division of plant No. 10 in Texas as compared with that of the parent plant and that of a similar progeny in Virginia cannot be explained on the basis of present knowledge of the subject.

A second experiment along the same line in which the plantings were made at Wellborn, Texas, Tifton, Ga. (Georgia Coastal Plain Experiment Station), and Columbia, S. C. (Sandhill Experiment Station), was started in the spring of 1940. In this case 15 plants were taken at Milano, Texas, and divided into three crown divisions of about equal size. One was replanted in similar soil at Wellborn, Texas, on March 5 and the other two were shipped to the eastern locations where they were planted on March 11. Excess roots available from the parent plants were utilized for determining the percentage of rotenone and chloroform extract.

The data in table 3 showing the relative growth of these plants by August 15, 1940, indicates that conditions at Tifton were most favorable to growth and those at

Table 2.—Comparison of percentages of rotenone and chloroform extracts of the roots of parent plants and crown division progenies of *Tephrosia virginiana* when grown in Texas and Virginia.

	Parent Plants (Milano, Texas)			Crown Division Progenies			
				Milano, Texas		Arlington, Virginia	
Plant No.	Durham color test[1]	Rotenone	Chloroform Extract	Rotenone	Chloroform Extract	Rotenone	Chloroform Extract
1	Deep blue (opaque)	[2]	5.40	1.45	6.50	1.83	7.90
2	Deep blue (opaque)	1.79	5.80	1.85	6.65	2.14	9.75
3	Deep blue (opaque)	1.92	9.10	1.72	9.75	2.76	11.35
4	Deep blue (opaque)	—	5.00	.70	5.15	[3]	—
5	Blue	—	5.60	1.28	7.40	1.25	6.50
6	Deep blue (opaque)	—	6.80	2.35	7.75	2.92	8.50
7	Blue	1.17	5.75	1.24	6.50	1.80	8.10
8	Deep blue (opaque)	1.43	6.25	2.11	8.25	3.05	10.25
9	Pale blue	2.02	9.75	1.81	11.15	2.27	11.75
10	Deep blue (opaque)	1.47	5.50	.45	4.35	1.96	8.60

[1] See footnote Table 1 for significance of color as indicator rotenone content.
[2] If no data are given there was insufficient material.
[3] Plant died.

Table 3.—Relative growth by August 15, 1940, of 15 plants of *Tephrosia virginiana* from crown divisions from identical parents after planting in Wellborn, Texas, Tifton, Ga., and Columbia, S. C., in March, 1940.

Crown Division No.	Length of Stalk (Inches) at			Produced Flowers and Seed at		
	Wellborn, Texas	Tifton, Georgia	Columbia, S. Car.	Wellborn, Texas	Tifton, Georgia	Columbia, S. Car.
1	16	18	15	X	X	
2	6	18	6		X	
3	10	15	6	X		
4	14	18	15		X	
5	14	13	8	X	X	X
6	15	18	12		X	X
7	15	20	13	X	X	X
8	12	18	15	X	X	
9	12	20	15		X	
10	17	20	15		X	
11	17	20	8	X	X	
12	16	20	14	X	X	
13	18	20	12	X	X	
14	15	15	5	X		
15	14	20	13		X	

Columbia resulted in much lack of uniformity. The relative thriftiness of the plants is also shown by the production of flowers and seed.

The plants were not disturbed in 1940 but were dug up in the summer of 1941 and the roots analyzed. The results are given in Table 4.

The quality of the plants grown at Tifton, Ga., compares with that of the lacking in this constituent. The highest percentage of chloroform extract in the parent plants and in the progenies at the two locations is that of plant No. 13 and that of plant No. 8 and its progenies is also high. There can be no question that the conditions under which the plants grew at Tifton enable or permit the plants to produce rotenone to the same or greater degree than is the case at Wellborn, Texas.

Table 4.—Comparison of percentages of rotenone and chloroform extract of the roots of plants of *Tephrosia virginiana* grown from crown divisions of the same parent in Texas, Georgia and South Carolina.

			Plants Grown from Crown Divisions at					
	Parent Plant		Wellborn, Texas		Tifton, Georgia		Columbia, S. Car.	
Crown Division No.	Rotenone	Chloroform Extract	Rotenone[1]	Chloroform Extract	Rotenone	Chloroform Extract	Rotenone	Chloroform Extract
1	0.58	10.50	.86	6.55	1.29	5.25	[2]	
2	1.98	8.05	[3]		2.39	7.45	.00	3.75
3	1.78	7.50	.00	8.00	2.08	7.65	.00	3.65
4	.00	6.51	[4]		.00	6.60	.50	4.30
5	.72	8.30	2.33	9.50	1.90	9.15	.29	4.35
6	2.10	7.25	3.14	8.25	2.96	7.25	.00	6.00
7	1.01	6.50	.97	7.50	1.69	7.15	.16	4.60
8	0.19	9.35	.53	11.40	.59	11.60	.00	5.50
9	1.64	8.50	1.29	8.80	2.16	9.40	.00	4.75
10	2.37	7.75	2.28	8.60	3.95	10.55	.33	5.00
11	2.72	8.75	2.38	7.55	2.44	7.65	.23	3.45
12	2.00	5.75	2.36	7.60	2.71	7.10	1.33	5.95
13	.72	11.35	1.84	11.50	2.96	12.25	.94	6.50
14	1.15	6.25	1.94	6.50	1.68	6.90	2.37	7.75
15	.00	7.95	.00	8.60	.00	7.35	1.13	5.75
Av.	1.26	8.02	1.53	8.49	1.92	8.22	.52	4.75

[1] Where no data are given there was insufficient material.
[2] Pale blue color with Durham test.
[3] Deep blue color with Durham test.
[4] Blue color with Durham test.

Wellborn, Texas, plants very much as the quality of the Arlington, Va., plants compared with that of the Texas plants in the previous experiment. Eight of the fifteen plants in comparison contained more rotenone at Tifton. In the case of parent plant No. 3, which contained 1.78 per cent rotenone, the crown division progeny at Tifton contained 2.08 per cent whereas that at Wellborn did not contain any. Parent plant No. 4 contained no rotenone and the crown division progeny at Tifton likewise contained none. That at Wellborn was too small to be analyzed but the Durham test suggests some rotenone. Parent plant No. 15 was another without rotenone and the progenies in both localities are likewise

At Columbia, S. C., radically different results were obtained. There the plants were grown in a single row in the typical sandy soil of the Sandhill district of the State. Wild plants on such soil in that region invariably give negative results with the Durham test. The progeny plants in this case are on the whole very low in chloroform extract which is generally indicative of low rotenone content. The only exception is plant No. 14 and this also has a good rotenone content. If all the plants in this location were deficient in rotenone there could hardly be any question that some condition of the soil or other environment definitely prevented rotenone from forming, but it is difficult to understand why a few of the plants

should not be thus affected. The curious fact is that the poor plants are all grouped and the last four plants in the row are much better, the last one containing 1.13 per cent rotenone whereas neither the parent nor the progenies at Wellborn and Tifton contained any.

The collaborator at Columbia who took up the plants reported that those at the lower end of the row (approximately Nos. 9 to 15) were much smaller than the others but the weight of the roots obtained did not correlate with top growth. It was suggested that stunting of the plants through some local condition in the lower half of the row as indicated by top growth might be responsible but apparently the condition affected the top growth rather than the root growth. It must be concluded that the environment in that particular locality has a definite tendency to influence rotenone formation in the plant but at the present knowledge of the plant and its reaction to various conditions is not adequate to provide the explanation. It follows, therefore that at Arlington, Va., and Tifton, Ga., plants propagated from crown divisions of plants of satisfactory rotenone content brought from elsewhere may be expected to produce a crop of equal quality but such results cannot always be expected in the Sandhill district in South Carolina. That being the case no single locality anywhere can safely be selected for commercial planting without a previous trial planting unless such locality is in a general region where wild plants of reasonable value may be found.

SUMMARY.—The roots of *Tephrosia virginiana*, a native legume known as devil's shoestring, sometimes contain rotenone and are believed to have possibilities as a commercial insecticide. In an extensive survey it was found that there are only a few restreited areas in the plant's range in which they generally contain some rotenone and in such areas individual plants can always be found which do not contain any while others growing nearby may contain several per cent. It is important to know whether this variation is due to environment or is a genetic character before commercial plantings may be recommended.

Experiments were conducted with seedlings and crown divisions in certain localities. Seed obtained in three localities where the quality of the wild plants is generally known, was planted at Arlington, Va., where wild plants have not been found to contain any rotenone, for comparison of the quality of the resulting roots. The results indicate that environment did not prevent rotenone from forming in the plants grown from seed obtained from plants in Texas and Georgia where they usually contain some rotenone. On the other hand, if the parent plants were lacking in this constituent the progeny did not develop any.

Plants grown from crown divisions obtained from plants of known quality in Texas were planted there and in Arlington Va., in one experiment and in another three such crown divisions were made, one replanted in Texas and the others planted at Tifton, Ga., where wild plants sometimes contain rotenone, and at Columbia, S. C., where they seldom if ever contain any.

The results in the first case showed that at Arlington, Va., the rotenone content of the crown division progeny after two seasons' growth is in most cases equal to or better than that of the progenies replanted in similar soil less than 50 miles removed from where the parents were taken. In the second case the rotenone content of the plants at Tifton, Ga., after two seasons' growth was in general as high as that of the plants grown at Wellborn, Texas, whereas at Columbia, S. C., some unknown condition evidently prevented rotenone formation in the plants except in a few at the end of the row.

The experiments appear to show that in general there are certain strains of the species that have the capacity to produce rotenone under most conditions but that certain environmental conditions not yet understood, can greatly modify this capacity.—3-26-43.

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Cotton Aphid Damage and Control in Texas[1]

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For a number of years the cotton aphid, *Aphis gossypii* (Glov.), has been recognized as a pest of considerable importance on cotton in Texas. During recent years the attempts made by investigators in Texas to measure aphid damage have not been entirely successful. This paper describes three experiments conducted at Waco, Tex., in 1942 on the control of the cotton aphid and the reduction in yield caused by it.

PLOT SIZE AND ARRANGEMENT.—The plots of experiments 1 and 2 were arranged in randomized blocks, each treatment being replicated 4 times. The plots of experiment 1 were each 10 rows wide and 0.05 acre in size and were separated from one another on the sides by 10 rows of untreated cotton and on the ends by untreated cotton equal in length to that of a plot. In other words, each dusted and check plot of experiment 1 was surrounded by buffers of untreated cotton equal in size to a plot. In experiment 2 the plots were 16 rows wide and 0.2 acre in size and were contiguous in a compact area. Experiment 2 was located in the same field and on the same rows as experiment 1 with only a 50-foot buffer of untreated cotton separating the experiments. The cotton in each experiment was uniform and apparently of equal potential production.

Experiment 3 was a large-scale test and the treatments were not replicated. The check plot was 58 rows wide and 1.8 acres in size; the plot dusted with calcium arsenate plus 1 per cent of nicotine was 64 rows wide and 4.5 acres in size; the plot dusted with calcium arsenate plus 0.5 per cent nicotine was 64 rows wide and 6 acres in size; and the plot dusted with the 1:2 mixture of basic copper arsenate and sulfur was 80 rows wide and 6.2 acres in size. The plot treated with calcium arsenate plus 1 per cent of nicotine was adjoined on the south by the check and on the north by the plot treated with calcium arsenate plus 0.5 per cent of nicotine, and the plot treated with basic copper arsenate and sulfur mixture was separated from the other plots on the southwest by a shallow ditch about 30 feet wide. So far as known, the land fertility and the potential production of cotton were the same in each plot. The land was very rich and the cotton grew unusually rank.

TREATMENTS AND RECORDS.—In experiments 1 and 2 the plots were dusted 8 times with a single-nozzle rotary hand gun between July 10 and August 13. In experiment 3, 7 applications were made with an 8-row tractor attachment between July 11 and August 12. All applications were made early in the morning except in one series of plots in experiment 2 in which calcium arsenate plus 1 per cent of nicotine was applied at midday. Five boll weevil infestation records were made in experiments 1 and 2 between July 16 and August 13 and 6 records were made in experiment 3 between July 20 and August 24. These records were made by counting the punctured squares found in 100 squares per plot in experiment 1, 200 squares per plot in experiment 2, and

[1] In cooperation with the Texas Agricultural Experiment Station.

[2] Thanks are extended to C. R. Parencia, Jr., H. L. Holbert, F. J. Patterson, R. J. Legett, and C. B. Cowan for assistance in making field-plot records, and to the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine, for the chemical analyses and particle-size determinations of insecticides used in the experiments reported herein.

Table 1.—Results of experiments against the boll weevil and cotton aphid.

TREATMENT	RATE OF APPLICATION PER ACRE	APHIDS PER SQUARE INCH OF LEAF AREA		SQUARES PUNCTURED BY BOLL WEEVIL	BOLLWORM INFESTATION		YIELD OF SEED COTTON PER ACRE
		Maximum	Average		Injured Squares	Injured Bolls	
	Pounds	*Number*	*Number*	*Per Cent*	*Per Cent*	*Per Cent*	*Pounds*
		Experiment 1					
Untreated check		1.2	0.7	14.1	6.5	7.2	977
Calcium arsenate	6.1	11.3	6.4	6.3	8.2	8.8	948
Calcium arsenate and sulfur 1:2, plus nicotine sulfate, 0.5 per cent nicotine	12.4	5.8	3.1	6.7	8.1	7.8	971
Cryolite	6.8	4.1	2.2	6.7	4.1	3.8	1,196
Calcium arsenate and nicotine sulfate, 1 per cent nicotine	6.2	5.1	2.6	6.0	6.6	6.3	1,199
Cryolite and nicotine sulfate, 1 per cent nicotine	6.1	2.7	1.3	6.1	4.9	5.2	1,211
Difference required for significance, 5 per cent level			1.54	1.5	2.9	2.8	197.6
		Experiment 2					
Untreated check		5.7	2.6	10.2	11.3	16.0	842
Calcium arsenate and nicotine sulfate, 0.5 per cent nicotine	6.1	14.7	7.4	5.1	7.9	9.4	925
Calcium arsenate and nicotine sulfate, 1 per cent nicotine, midday applications	6.4	10.4	6.0	6.6	8.3	9.6	926
Calcium arsenate	6.4	9.4	5.6	5.4	7.1	7.8	976
Calcium arsenate and nicotine sulfate, 1 per cent nicotine, early-morning application	6.4	5.7	3.2	6.5	8.6	9.3	1,036
Alternate applications of calcium arsenate and a mixture of calcium arsenate and nicotine sulfate, 2 per cent nicotine	6.6	1.4	.8	5.3	7.0	7.4	1,106
Difference required for significance, 5 per cent level			3.58	1.4		3.9	
		Experiment 3					
Untreated check		3.6	0.8	37.2	16.2	16.8	705
Calcium arsenate and nicotine sulfate, 0.5 per cent nicotine	9.8	23.9	8.3	11.0	14.4	6.6	769
Calcium arsenate and nicotine sulfate, 1 per cent nicotine	10.4	5.9	1.6	13.3	17.9	7.1	937
Basic copper arsenate and sulfur 1:2	17.4	2.4	.7	11.5	10.4	7.4	1,228

600 squares per plot in experiment 3.

The cotton aphid population records were made by counting the aphids on a square inch of leaf area near the center of the fourth leaf from the top of 100 plants in each plot of experiments 1 and 2 and 300 plants per plot in experiment 3, with the exception that after aphids became extremely abundant the samples were reduced by half. Five infestation records were made in Expts. 1 and 2 between July 16 and August 14, and five in Expt. 3 between July 20 and August 24.

Records on the bollworm were made by counting the injured forms in 100 squares or bolls in each plot of experiments 1 and 2 and in 600 squares or bolls in each plot of experiment 3. In experiments 1 and 2 three square-injury records were made between July 31 and August 13 and 2 boll-injury records were made on August 7 and August 13. In experiment 3 four square-injury records were made between July 20 and August 10 and three boll-injury records between August 4 and August 24.

The yield records were made on half the plot area in experiments 1 and 2 and on the entire area of the large plots in experiment 3. In experiment 1 two rows on each side and a portion of each end and in experiment 2 three rows on each side and a portion of each end of each plot

were not included in the harvested area.

The calcium arsenate used in the experiments contained on an average 40.4 per cent of total arsenic pentoxide and 11.1 per cent of water-soluble arsenic pentoxide (New York Method). The cryolite was synthetic and contained 87.4 per cent of sodium fluoaluminate. The sulfur was 325-mesh and 96 per cent pure. The nicotine used in the experiments was from 40-per cent nicotine sulfate. Five per cent of hydrated lime was added to calcium arsenate and cryolite when nicotine sulfate was used, in order to make sure that these dusts contained sufficient free lime to liberate the nicotine.

RESULTS.—Infestation records, dust applications, and yield records for these three experiments are summarized in table 1. Infestation and yield data for experiments 1 and 2 were analyzed by analysis of variance and when differences between the treatment means were found to be significant, as indicated by the *F* test, the minimum difference required for significance is shown in the table. It will be noted that while the boll weevil infestation was light in both experiments, it was somewhat higher in experiment 1 than in experiment 2, whereas the bollworm infestation was higher in experiment 2 than in experiment 1. On the whole, the infestation records show that each insecticide gave control of the boll weevil and the bollworm where injurious infestations existed and that the differences in yields between insecticidal treatments were due mostly to aphid injury or control.

In experiment 1 the three treatments that gave the best aphid control were the only ones that gave significant increases in yield. The gains over the checks were 234 pounds of seed cotton per acre from cryolite plus 1 per cent of nicotine, 222 pounds from calcium arsenate plus 1 per cent of nicotine, and 219 pounds from cryolite. The plots receiving the 1:2 mixture of calcium arsenate and sulfur plus 0.5 per cent of nicotine and the undiluted calcium arsenate had significantly higher aphid populations and yielded slightly less than the check. The records from this experiment show that the damage from aphids averaged 243 pounds of seed cotton per acre.

In experiment 2 alternate applications of calcium arsenate and calcium arsenate plus 2 per cent of nicotine gave the best control of the aphid and the highest yield, a gain of 264 pounds per acre over the check. The next best control of the aphid, resulting in a gain of 194 pounds, was from calcium arsenate plus 1 per cent of nicotine applied early in the morning. Calcium arsenate plus 1 per cent of nicotine applied at midday was not effective in controlling the aphid, as was shown by the infestation record and a gain of only 84 pounds. The aphid infestation was significantly lower in the alternate applications of calcium arsenate plus 2 per cent of nicotine than in the calcium arsenate alone, calcium arsenate plus 1 per cent of nicotine, applied at midday, and calcium arsenate plus 0.5 per cent of nicotine. The three last-named insecticides resulted in gains in yield of 134, 84, and 83 pounds, respectively, or an average of 100 pounds per acre. As the gain from the alternate applications of calcium arsenate plus 2 per cent of nicotine was 264 pounds, the difference of 164 pounds may be attributed to loss caused by aphids.

Each insecticide in experiment 3 gave adequate control of a fairly high infestation of the boll weevil. In the untreated check the average seasonal weevil infestation was 37.2 per cent and the peak was 66.7 per cent of punctured squares. The boll-injury records show that the three insecticides gave about equal control of the bollworm, whereas the square-injury records indicate that the 1:2 mixture of basic copper arsenate and sulfur gave slightly better control than did either of the calcium arsenates.

In order to obtain about the same bollworm control in the calcium arsenate plots as in the basic copper arsenate-sulfur plot of experiment 3, the poundages of the calcium arsenate were almost doubled (average of 18.3 pounds per acre) at the peak of the bollworm infestation.

In experiment 3 there was more aphid damage in the plots treated with calcium arsenate than is indicated from the aphid-infestation records in table 1. These records were made on the fourth leaf from the top and at the time of record taking most of the aphids were on the lower leaves, fruits, and stems. At one time special counts showed more than twice as many aphids on the bottom leaves than on the fourth leaf from the top. It was estimated that from 50 to 75 per cent of the leaves were prematurely shed by

aphids in the plot dusted with calcium arsenate plus 0.5 per cent of nicotine; and, although the records might not indicate it, there was some damage and leaf drop from aphids late in the season in the plot treated with calcium arsenate plus 1 per cent of nicotine. Calcium arsenate plus 1 per cent of nicotine gave adequate aphid control until late in the season, when aphids migrated from the adjoining plot which was treated with calcium arsenate plus 0.5 per cent of nicotine. As was the case in experiment 2, the 0.5 per cent of nicotine gave very little control of aphids. There was also some spread of aphids to the check plot, which was contiguous in the same block. There either was very little, if any, migration to the plot treated with basic copper arsenate and sulfur, or the 30-foot noncotton buffer between this plot and the other plots apparently served as an effective barrier, preventing aphid spread. Although there was a build-up of aphids and some honeydew on the lower leaves in the plot dusted with basic copper arsenate and sulfur, the infestation did not reach the point of causing leaf-drop or any noticeable injury.

The yield records in experiment 3 show a gain over the check of 523 pounds from basic copper arsenate and sulfur, 232 pounds from calcium arsenate plus 1 per cent of nicotine, and 64 pounds from calcium arsenate plus 0.5 per cent of nicotine. The calcium arsenate containing 1 per cent of nicotine produced 168 pounds of cotton more than did the calcium arsenate containing 0.5 per cent of nicotine, and all this difference represents loss due to aphid damage. The basic copper arsenate with sulfur produced 459 pounds more than calcium arsenate plus 0.5 per cent of nicotine. Most of this difference of 459 pounds was no doubt due to aphid damage. Ivy and Ewing (1943) show that basic copper arsenate has a much greater residual effect in killing the cotton leafworm, *Alabama argillacea* (Hbn.), than has calcium arsenate, and it is possible that this increased residual effect might have been a factor in experiment 3 in increasing the yield from basic copper arsenate by giving increased late-season control of the bollworm and boll weevil.

SUMMARY.—Two experiments conducted at Waco, Tex., in 1942 showed reductions in cotton yield of 164 and 243 pounds of seed cotton per acre which could be attributed to cotton aphids. In one experiment where the aphid damage could not be accurately measured there was a difference of 459 pounds between insecticidal treatments, most of which was due to aphids.

It was found that nicotine sulfate mixed with calcium arsenate to contain 0.5 per cent of nicotine did not satisfactorily control the aphid. Calcium arsenate in alternate applications with calcium arsenate plus 2 per cent of nicotine and calcium arsenate plus 1 per cent of nicotine in each application gave considerable control of the aphid, the former being slightly the better. Cryolite produced a lower infestation of aphids than did calcium arsenate. Early morning applications of calcium arsenate plus 1 per cent of nicotine were more effective in controlling the aphid than were midday applications. A nondusted buffer of 30 feet or more greatly reduced the migration of aphids between plots.—4-1-43.

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Idaho State quarantines were revised on May 22, 1943, to include additional area infested with the oriental fruit moth, the European corn borer and the potato tuber moth, and to provide for fumigation of used containers of host fruit of the oriental fruit moth.

The European corn borer quarantine of Tennessee was revised June 1, 1943, to bring the regulated area in line with current quarantines.

Some Factors Influencing Bollworm Populations and Damage

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In the course of experiments on the control of the cotton flea hopper, *Psallus seriatus* (Reut.), and the boll weevil, *Anthonomus grandis* Boh., conducted by the senior author in Texas since 1933, it has been observed frequently that populations of the bollworm, *Heliothis armigera* (Hbn.), and damage by this insect were greater in plots of cotton dusted with arsenicals than in adjacent undusted plots. This fact was first brought to public attention by Bishopp (1929), although it had been noticed several years before by entomologists engaged in cotton insect control.

Sherman (1930) presented data collected in 1927 showing that cotton dusted with calcium arsenate early in the season for control of the boll weevil later developed a higher bollworm infestation than did undusted cotton. He states, " . . . It appeared without exception that bollworm damage was heaviest on the areas that had been dusted or in nearby fields. No attempt is made to explain this infestation but nevertheless in places the evidence seemed striking." Fletcher (1929) made the following statement regarding Sherman's report: " . . . Mr. Sherman's observations are borne out by those of other members of the staff and by those of Mr. George Chance, manager of the plantation on which the observations were made."

On the other hand, Thomas & Dunnam (1931) state, " . . . It may be difficult to see any difference in cotton fields at the time the injury is noticed, but, because of richer soil, more abundant moisture, time of planting, or wider spacing, cotton plants may have been growing more rapidly in some fields than in others when oviposition took place, or differences may have appeared in parts of the same field if the soil fertility was uneven or the rainfall irregular. The occurrence of these conditions apparently explains the statement made by Sherman that bollworm damage was heaviest on areas that had been dusted."

Moreland & Bibby (1931) gave the purpose of 3 years' field experiments as, " . . . first, to check up on the suggestion that such use of insecticides might under some conditions actually result in an increased infestation . . . "; and in describing the results they stated, " . . . At no time was there the slightest indication that these applications tended to increase infestation. In fact the results were so directly the opposite that there is quite obviously no need for fear on this score."

The seriousness of the problem of increased bollworm populations which often follow applications of calcium arsenate was brought forcibly to the attention of cotton growers and entomologists in Texas and other States during 1941 because of the succulent condition of the cotton plants due to abundant rains and the widespread early-season dusting for boll weevil control. Cotton growers who applied 10 to 12 pounds of calcium arsenate per acre when bollworm eggs were hatching and the larvae were quite small usually obtained good control; but in many instances muddy fields, loss of applications from rains, inability to obtain poison, or other factors hindered dusting at the proper time and prevented effective bollworm control. In the latter instances the damage from bollworms frequently offset the gains from earlier dusting for boll weevil control, and in some cases the increased bollworm damage actually resulted in lower yields in the dusted than in the undusted cotton.

Experimental Records.—The records of experiments conducted by the Bureau of Entomology at Port Lavaca, Edna, College Station, and Waco, Tex., since 1928 show that more eggs and larger larval populations of the bollworm were frequently found on the plots dusted with arsenicals than on the undusted check plots. Tables 1, 2, and 3 summarize these records.

In extreme cases there were more than twice as many eggs and seven times as many larvae and injured squares in the dusted as in the adjacent undusted plots. In one series of experiments (Table 2) on boll weevil control where the dosage of calcium arsenate was neither sufficiently

[1] In cooperation with the Texas Agricultural Experiment Station.

Table 1.—Comparison of abundance of bollworm larvae and bollworm-injured squares in undusted (check) plots and adjacent plots dusted[1] for flea hopper control, Port Lavaca, Tex.

Year	Number of Plots		Bollworms per Acre			Injured Squares		
	Check	Dusted	Check Plot	Dusted Plot	Increase, Dusted Over Check, Per Cent	Check, Per Cent	Dusted, Per Cent	Increase, Dusted Over Check, Per Cent
1933	4	4	2,651	8,798	232	15.4	31.9	107.1
1937	6	24	818	1,769	116	8.0	12.2	52.5
1938	6	24	1,369	3,270	139	9.4	18.8	100.0

[1] In 1933 two of the plots were dusted with 1–3 Mixture of Paris green and calcium arsenate and two plots with sodium fluosilicate; the last dust applications were made June 26–29, and the infestation records were made July 5–10. In 1937 mixtures of sulfur and calcium arsenate or paris green and undiluted calcium arsenate were used; dust applications were made July 15, 20, 26, 31, and August 5, 10, and 23, and the infestation records were made August 7, 14, and 19. In 1938 mixtures of sulfur and arsenicals were applied on June 13, 14, 18, 24, and 29, and the infestation records were made July 13.

heavy nor the applications properly timed for bollworm control, the increased damage by bollworms and aphids more than offset the gains from boll weevil control and resulted in an average reduction in yield of 163 pounds of cotton per acre, or 17 per cent. In most cases, however, the increased gains from control of the flea hopper or boll weevil were more than enough to overcome the increased damage from bollworms and aphids.

Table 2.—Comparison of dusted[1] and undusted check plots in four field-plot experiments conducted for boll weevil control at Edna, Tex., 1938.

Items of Record	Average of Four Undusted Check Plots	Average of 16 Dusted Plots	Increase, Per Cent: Dusted Over Check
Bollworms per acre	487	3,188	541
Bollworm square injury, per cent	2.1	15.4	633
Boll weevil punctured squares, per cent	24.6	9.6	−61
Yield, pounds seed cotton per acre	948	785	−17

[1] Plots were dusted with calcium arsenate or mixtures of calcium arsenate and sulfur on June 29, July 5, 11, and 19 for the boll weevil and with calcium arsenate on July 28 for bollworm control; check plots were not dusted. Bollworm records were made July 26 and 27.

It should be remembered that dusting cotton with calcium arsenate does not always result in increased bollworm populations and damage, and that when applied at the correct time and in proper dosages it will control the bollworm. In some of the bollworm control experiments conducted by the Bureau, increases in yield following its use have sometimes amounted to more than 1,000 pounds of seed cotton per acre. Growers also have often saved their crops from almost complete destruction by bollworms by timely applications of calcium arsenate.

Several factors contribute to the seeming paradox of increased bollworm populations following the use of an insecticide recommended for their control. Since 1933 it has been observed that in dusted plots having a large aphid infestation at the time bollworm moths migrate to cotton there is nearly always a conspicuous increase in bollworm numbers as compared with undusted cotton. Fletcher (1929)

Table 3.—Comparison of abundance of bollworm eggs in undusted plots and plots dusted with calcium arsenate, College Station, Tex.

Year	Number of Experiments	Insecticide Applications in Various Plots, Number			Ave. Number of Egg Inspections Per Plot	Average Number Eggs Per Acre[1]		Increase in Eggs, Dusted Over Undusted Per Cent
		Max.	Min.	Ave.		Check	Dusted	
1928	5	10	5	6.7	5.2	206	264	28.2
1929	9	17	5	10.3	10.0	2,217	3,432	54.8
1930	5	11	8	9.6	11.0	1,756	2,316	31.9
1931	13	5	4	4.8	4.5	371	383	3.2
1933	9	5	3	4.3	8.0	2,155	2,976	38.1
1935	9	12	4	8.6	5.3	9,241	9,338	1.0
1936	22	7	2	4.4	4.1	1,083	2,363	118.2
1937	10	3	3	3.0	3.0	2,208	2,923	32.4

[1] Computed from examination of 30 to 300 plants per plot at each inspection.

suggested that since bollworm moths were attracted to molasses and water solutions, they might also be attracted to aphid honeydew. No data are available, however, to substantiate this entirely plausible theory. Bollworm moths utilize sugars in their metabolism (Ditman & Cory 1933), and their longevity and reproductivity are influenced by the food available to them (Quaintance & Brues 1905). Thus it would seem that an abundance of food in the form of aphid honeydew may contribute to increased longevity and fecundity, and that this may partly explain increased egg depositions associated with in undusted fields at Tallulah, La. Since these predators also feed on bollworm eggs and small larvae, a reduction in their numbers caused by arsenicals would favor an increase in bollworm populations.

It also appears from experiments conducted by the authors at Waco in 1940 and 1941 that an abundance of aphids affects the food balance of various predators that normally live on aphids and eggs and young larvae of the bollworm, as they will eat more aphids and consequently less of the bollworm forms. The causes of the increase in cotton aphids following the use of arsenicals is a separate problem

Table 4.—Consumption of bollworm eggs by different predators, Waco, Tex., 1941.

Predator[1]	Stage of Development	Number of Predators Tested	Average Period of Observation, (Days)	Number of Bollworm Eggs		
				Total Provided	Total Consumed	Consumed Per Predator Each Day
Chrysopa rufilabris Burm.	Larva	3	8.7	750	714	27.4
Hippodamia convergens Guér.	Adult	7	9.6	2,052	1,648	24.5
Coleomegilla fuscilabris, (Muls.).	Adult	3	7.6	625	503	22.1
Hippodamia convergens Guér.	Larva	2	6.0	190	169	14.1
Collops balteatus Lec.	Larva	1	5.0	70	55	11.0
Collops balteatus Lec.	Adult	4	8.4	442	296	8.8
Podisus maculiventris (Say)	Adult	2	7.0	120	74	5.3
Zelus socius Uhl.	Adult	1	7.0	40	23	3.3
Zelus renardii Kol.	Nymph	3	8.0	80	68	2.8
Orius insidiosus (Say)	Nymph	11	4.3	200	133	2.8
Geocoris punctipes (Say)	Adult	3	6.3	80	51	2.7
Orius insidiosus (Say)	Adult	29	8.1	727	546	2.3
Scymnus creperus Muls.	Adult	7	6.3	132	91	2.1
Zelus renardii Kol.	Adult	4	6.2	90	45	1.8
Melanophthalma distinguenda (Com.)	Adult	2	4.5	30	15	1.7

[1] Identified by the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

aphid infestations. Here again, however, confirming evidence is lacking.

Some of the factors that upset the biological balance and contribute to increased aphid populations following the use of arsenicals are conducive to increased bollworm populations. Rainwater & Bondy (1939) observed a reduction of coccinnelid adults and chrysopid larvae, but no reduction of aphid parasitization, on cotton fields dusted with calcium arsenate at Florence, S. C., in 1939. They found that adult coccinellids caged on aphid-infested plants dusted with calcium arsenate were killed by the arsenical. Cage tests at Waco in 1940 and 1941 also showed that several coccinellid predators of aphids and bollworms were killed by arsenicals. Smith & Fontenot (1942) found considerably fewer coccinellids and chrysopids in dusted than that will not be discussed in detail. The results of Dunnam & Clark (1941), however, show that the physiological effect of the calcium arsenate on the plants or aphids, or both, causes an accelerated rate of aphid reproduction, and that factors other than reduction of predators are at least partly responsible for the increase in aphid populations. The reduction in yields caused by heavy aphid infestation is often heavy, and further complicates evaluation of the bollworm damage.

Relative Egg Consumption by Various Predators.—Several predaceous insects collected from cotton were confined individually in jelly glasses fitted with slightly moistened blotting paper and supplied daily with eggs deposited by insectary-reared bollworm moths. A regular effort was made to supply more eggs than

the predator could consume. This was usually accomplished, but individuals of *Chrysopa rufilabris* and *Coleomegilla fuscilabris* frequently consumed all the eggs given them, and without doubt would have eaten more. The maximum number of eggs destroyed in a day by a single predator was 275 by an adult of *Hippodamia convergens*. Results of these feeding tests with predators are summarized in table 4.

were fastened with albumen to each of 10 leaves per plant. Various species of predaceous insects were then released on individual plants with and without aphids present, and observations were made on the number of eggs hatching and the number of bollworms reaching the second instar.

As shown in table 6, the presence of aphids greatly influenced the extent to which *Orius insidiosus* fed on bollworm

Table 5.—Comparison of bollworm egg and cotton aphid consumption by adult *Orius insidosus* and *Hippodamia convergens* when supplied daily with bollworm eggs only, with aphids only, and with both eggs and aphids in the insectary at Waco, Tex., 1941.

Predator	Food Supplied	Number of Predators	Average Period of Observation (Days)	Bollworm Eggs Consumed per Day	Aphids Consumed per Day
Orius insidiosus	Bollworm eggs	7	5.3	1.9	—
	Aphids	6	5.7	—	4.5
	Bollworm eggs and aphids	7	7.3	1.1	2.3
Hippodamia convergens	Bollworm eggs	7	9.6	24.5	—
	Aphids	5	8	—	13.6
	Bollworm eggs and aphids	5	6.8	12.8	9.1

INFLUENCE OF APHIDS ON THE DESTRUCTION OF BOLLWORM EGGS AND LARVAE BY PREDATORS.—Studies were made in the insectary and in field cages during 1941 to determine the extent to which feeding by predaceous insects on bollworm eggs and larvae is influenced by the availability of an abundance of other food, such as exists under field conditions when a heavy aphid infestation occurs.

In the insectary studies, individuals of *Orius insidiosus* and *Hippodamia convergens* caged separately were supplied daily with both bollworm eggs and aphids placed on tender young cotton leaves so that they could choose the food most attractive to them. Other individuals of these species were supplied with either bollworm eggs or cotton aphids. The daily consumption of eggs and aphids under the conditions of these tests is shown in table 5. The daily egg consumption of *H. convergens* and *O. insidiosus* was cut almost in half when aphids were present.

For the tests in the field, cotton plants supporting large aphid populations were covered with fine-mesh, brass-screen cages. Immediately before the plants were caged, all insects except those utilized in the experiments were removed, and 10 bollworm eggs deposited by insectary-reared moths

eggs. Sixteen times as many eggs hatched on the plant with an abundance of aphids as hatched on the plant on which no food except the eggs was available, and in the latter case not a single bollworm reached the second instar as compared with 15 second instars on the aphid-infested plant. Barber (1936) also found that the availability of other food—aphids, thrips, eggs and young larvae of other species of Lepidoptera, and other small insects—affects the efficiency of *O. insidiosus* as a destroyer of *Heliothis* eggs on corn. Similar

Table 6.—Results of field cage tests in which bollworm eggs were exposed to predators on cotton plants with and without cotton aphids, Waco, Tex., 1941.

Predator	Number of Predators	Aphids	Number of Bollworm Eggs Hatched[1]	Number of Bollworms Reaching Second Instar
Orius insidiosus	10	None	3	0
		Numerous	47	15
Crysopa sp., larvae	5	None	31	5
		Numerous	39	9
Check		None	55	29
Scymnus creperus, adults	10	None	20	2
		Numerous	38	9
Collops balteatus, adults	5	None	0	0
		Numerous	24	6
Zelus renardii, adults	5	None	52	0
		Numerous	59	0
Check		None	61	22

[1] 100 bollworm eggs placed on each plant.

results were obtained with most of the other insects tested. In the presence of *Collops balteatus* no eggs on the aphid-free plants hatched, but 24 hatched on the aphid-infested plants. The variation in egg hatch and larval survival between aphid-infested and aphid-free plants was not so pronounced with *Scymnus creperus* or *Chrysopa* sp., but in each case more eggs hatched and more larvae survived on the aphid-infested than on the aphid-free plants. Although a normal hatch of eggs occurred in cages containing *Zelus renardii*, none of the newly hatched larvae reached the second instar in the presence of this predator.

SUMMARY.—Timely applications of heavy dosages of calcium arsenate control the bollworm, but when the dosage is too light or when applications are not made at the proper time, cotton dusted with calcium arsenate becomes more heavily infested with bollworms than does undusted cotton.

The increase in bollworm infestation is frequently associated with increased aphid populations after the plants have been dusted with arsenicals, and this may be due partly to the attraction of bollworm moths to aphid honeydew for food.

Twelve species of predaceous insects found on cotton readily fed and survived on bollworm eggs, and some consumed large numbers of eggs. The average consumption by individuals of three species was more than 22 eggs per day, and one individual of *Hippodamia convergens* consumed 275 eggs in a single day.

Laboratory and field-cage tests showed that when aphids were abundant the predators permitted larger numbers of bollworm eggs to hatch and larvae to survive than when aphids were absent. This seems to be an important factor in causing increased bollworm populations on dusted cotton.—3-4-43.

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WAR ON INSECTS

Such is the title of a circular recently issued by the Milk Sub-Committee of the Association's Committee on the Cooperation of Entomology with the War Effort.

The task assigned to sub-committees was the assembly of information needed to stimulate insect control and to secure the distribution, in the most effective form, of such information to those who might need and use it.

In this task certainly this particular sub-committee has far exceeded what might have been expected from it, especially in the format in which the information is distributed and the very effective arrangement and illustration of the most pertinent facts. The presentation may well serve as a model for other groups.

The highest praise is due the sub-committee which consists of Dr. Ed. M. Searls and Dr. W. E. Dove, Dr. Searls having been in immediate charge of the publication.

Dosages of Insecticides to Control the Boll Weevil and the Bollworm

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The war has increased the need for reducing poundages of arsenicals used in controlling insects. A large amount of arsenic, mostly in the form of calcium arsenate, is used annually throughout the Cotton Belt for control of cotton insects. For several years the Division of Cotton Insects of this Bureau, has been conducting numerous experiments in an effort to find a satisfactory substitute for calcium arsenate and to determine whether reduced dosages of arsenicals would give adequate control of the boll weevil, *Anthonomus grandis* Boh., and other cotton insects. These investigations were continued in 1942 and included suggestions made by the Committee on Coordination of Entomology with the War Effort.

Two field-plot experiments were conducted at Waco, Tex., in 1942 to determine whether reduced dosages of calcium arsenate were effective against the boll weevil and whether cryolite could be substituted for calcium arsenate as an effective control of this insect.

Two field-plot experiments were also conducted at Waco, Tex., on the control of the bollworm, *Heliothis armegera* (Hbn.). Calcium arsenate at the rate of 8 to 10 pounds per acre per application has been the standard recommendation for control of the bollworm on cotton. Cage tests in 1940 (Moreland *et al.* 1941) and field-plot tests in 1941 (Ewing & Moreland, 1942) showed that basic copper arsenate, lead arsenate, and cryolite were each more effective than calcium arsenate when applied at the regular dosage of 8 pounds per acre. An experiment was conducted in 1942 comparing increased dosages of calcium arsenate and decreased dosages of basic copper arsenate. Another experiment on the bollworm was conducted, similar to the tests of 1941, comparing calcium arsenate, cryolite, lead arsenate, and basic copper arsenate at approximately 8 pounds per acre per application. The 1942 experiments are presented in this paper.

Plots, Treatments, and Records.—The plots were arranged in randomized blocks and there were 4 replicates of each treatment in each experiment. In 2 of the experiments, Nos. 1 and 4, the plots were 16 rows wide and 1/5 acre in size; in experiment 2 the plots were 16 rows wide and 1/6 acre in size; and in experiment 3 the plots were 10 rows wide and 1/10 acre in size. The entire plots were utilized in making the dust applications but infestation records were made on the 6 or 8 middle rows.

The dusts were applied with single-nozzle rotary hand guns during the early morning and at approximately 5-day intervals. Infestation records were made at weekly intervals, or as near thereto as possible. In experiments 1 and 2 for control of the boll weevil 200 squares were inspected per plot for the infestation record, whereas in the two bollworm-control experiments 100 squares per plot were inspected, counting the weevil-punctured squares. Records on the bollworm were made by counting the injured squares or bolls in 100 squares or bolls in each plot, those on the cotton aphid by counting the aphids on a square inch of leaf area near the center of the fourth leaf from the top of 100 plants in each plot of experiments 1 and 2 and of 50 plants in each plot of experiments 3 and 4, and those on the cotton flea hopper by counting the adult and nymphal flea hoppers on 100 main-stem terminals in each plot.

In each experiment the yield records were made on half the plot area. In the 16-row plots 3 rows on each side and a part of each end, and in the 10-row plots 2 rows on each side and a part of each end, were left as buffers.

The insecticides used were as follows:

Calcium arsenate: 3.5 per cent water-soluble arsenic pentoxide (New York method), 42.4 per cent total arsenic pentoxide, with a surface mean diameter of particles 0.7 micron in experiment 1 and 11.1 per cent water-soluble arsenic (New York method), and 40.4 per cent total arsenic pentoxide in the other experiments.

Lead arsenate: 0.47 per cent water-soluble arsenic pentoxide, 32.8 per cent total arsenic pentoxide.

Synthetic cryolite: 85.1 per cent sodium

fluoaluminate in experiment 1, and 87.4 per cent sodium fluoaluminate in experiments 2 and 4.

Sulfur: 325 mesh, 84.6 to 96 per cent pure.

Basic copper arsenate: 0.1 per cent water-soluble arsenic pentoxide, 38.7 per cent total arsenic pentoxide, 55.1 per cent CuO, surface mean diameter 1.5 microns.

BOLL WEEVIL.—When treatment was begun, 42.3 to 47.9 per cent, or an average of 45.1 per cent, of the squares were punctured in the various plots of experiment 1, and 31.4 to 37.1 per cent, or an average of 34.3 per cent, were punctured in experiment 2. Three weevil-infestation records were made in experiment 1 between June 30 and July 17, and four were made in experiment 2 between July 13 and August 3. Hot, dry weather reduced the infestation very rapidly in both experiments, the seasonal average after dusting began being only 21.5 and 20.9 per cent in the check plots of experiments 1 and 2, respectively. Experiment 1 received five dust applications between June 19 and July 16, and experiment 2 received six, one of which was washed off by rain, from July 4 to August 1. There was no appreciable damage from cotton flea hoppers in either experiment, nor any from bollworms in experiment 1. Three bollworm square-injury records were made between July 20 and August 3 and one bollworm boll-injury record on August 3 in experiment 2. Three aphid-infestation records were made in experiment 1 between June 30 and July 17 and six in experiment 2 between July 13 and August 27. There was very little if any damage from aphids in either experiment.

Table 1.—Results of experiments for boll weevil control.

Treatment	Rate of Application per Acre	Squares Punctured by Boll Weevil	Aphids per Square Inch of Leaf Area		Bollworm Infestation		Yield of Seed Cotton per Acre
			Maximum	Average	Injured Squares	Injured Bolls	
	Pounds	*Per Cent*	*Number*	*Number*	*Per Cent*	*Per Cent*	*Pounds*
		Experiment 1					
Untreated check		21.5	0.12	0.08			852
Calcium arsenate	6.5	9.0	2.40	1.32			838
Calcium arsenate and sulfur 1:2	12.4	10.0	.27	.19			914
Calcium arsenate and sulfur 1:3	13.5	11.4	.19	.10			822
Calcium arsenate and sulfur 1:5	13.6	13.8	.21	.12			891
Cryolite	7.2	9.4	.45	.21			858
Cryolite and sulfur 1:2	12.4	11.4	.80	.32			863
Cryolite and sulfur 1:3	12.8	11.7	.10	.07			806
Difference required for significance, 5 per cent level		4.8		0.578			
		Experiment 2					
Untreated check		20.9	0.80	0.17	11.6	12.8	844
Calcium arsenate	6.1	11.8	13.08	2.93	9.6	10.5	985
Calcium arsenate and sulfur 1:1	11.9	11.7	10.55	2.23	8.6	11.0	925
Calcium arsenate and sulfur 1:3	13.0	11.9	4.52	.92	9.9	14.0	902
Calcium arsenate and sulfur 1:7	14.1	12.0	2.08	.47	11.7	15.3	870
Cryolite and sulfur 1:1	11.8	13.3	2.51	.55	6.2	5.8	980
Cryolite and sulfur 1:3	12.4	15.6	.36	.13	8.6	6.8	1,028
Cryolite and sulfur 1:7	13.4	12.8	.68	.20	8.7	11.3	1,002
Difference required for significance, 5 per cent level		3.7			2.8	5.2	

Results of the experiment are shown in table 1. While the weevil infestation was too low in each experiment to show any marked results, in experiment 2 the three dilutions of calcium arsenate reduced the weevil infestation to lower levels (average, 11.9 per cent) than did similar dilutions of cryolite (average, 13.9 per cent). In experiment 1 the yields did not show any significant difference between treatments; the average yield of the dusted plots was 4 pounds greater than that of the check.

In experiment 2 there was damage from the bollworm, and the infestation records show that cryolite gave better control of this insect than did calcium arsenate. Most of the differences in yield were no doubt due to control of the bollworm. The bollworm injury to squares was significantly lower in each of the cryolite dilutions and in the 1:1 mixture of calcium arsenate and sulfur than in the check. The bollworm injury to bolls was significantly lower in the 1:1 and 1:3 cryolite dilutions than in the check. The gains from the three dilutions of cryolite averaged 159 pounds and from the three dilutions of calcium arsenate 55 pounds per acre.

BOLLWORM.—Experiments 3 and 4 were located on the same farm but in different fields. The cotton in experiment 3 was about a month older and much further advanced in fruiting than that in experiment 4. When treatment was begun, the various plots of experiment 3 averaged 20.0 eggs per 100 terminals and 16.3 per cent bollworm-injured squares, and experiment 4 averaged 27.9 eggs and 5.9 per cent injured squares. Experiment 3 was started on July 23 and experiment 4 on July 24. Each experiment received 3 dust applications, the last in experiment 3 was on August 1, and the last in experiment 4 was on August 3. Two bollworm square-injury records and two boll-injury records were made in experiment 3 and three square-injury records and two boll-injury records were made in experiment 4 between July 29 and August 12.

During the period of treatment and fruiting the boll weevil infestation did not exceed 10.8 per cent in any plot, the average in the checks being 8.4 per cent in experiment 3 and 8.0 per cent in experiment 4. Two records were made in experiment 3 and three in experiment 4 between July 29 and August 12. These records indicated no appreciable damage from weevils. There was no damage from flea hoppers. Three aphid-infestation records were made in each experiment between August 5 and 26. In experiment 3 each of the plots dusted with calcium arsenate had almost twice as many aphids as the plots dusted with basic copper arsenate and sulfur. The aphid infestation was higher in the plots dusted with basic copper arsenate and sulfur than in the check. There was a comparatively high aphid infestation in each treatment of experiment 4. The aphid infestation was short lived in each experiment; consequently, there was very little, if any, damage from this insect.

In experiment 3 there was very little

Table 2.—Results of experiments for bollworm control.

Treatment	Rate of Application per Acre	Bollworm Infestation		Squares Punctured by Boll Weevil	Aphids per Square Inch of Leaf Area		Yield of Seed Cotton per Acre
		Injured Squares	Injured Bolls		Maximum	Average	
	Pounds	*Per Cent*	*Per Cent*	*Per Cent*	*Number*	*Number*	*Pounds*
		Experiment 3					
Untreated check		15.3	9.9	8.4	7.3	3.7	835
Calcium arsenate 8 pounds	8.2	9.3	4.4	5.4	11.5	10.4	1,060
Calcium arsenate 12 pounds	12.4	10.6	3.8	4.8	12.8	10.8	1,110
Calcium arsenate 16 pounds	15.8	9.3	3.2	4.1	13.7	10.6	1,232
Basic copper arsenate and sulfur 1:1	16.0	8.9	5.7	6.2	9.4	6.3	1,206
Basic copper arsenate and sulfur 1:2	16.0	12.8	5.9	5.4	8.8	5.5	1,108
Difference required for significance, 5 per cent level		3.1	2.7				150.4
		Experiment 4					
Untreated check		12.3	12.8	8.0	8.2	4.4	592
Calcium arsenate	8.6	7.5	3.8	3.5	15.0	8.3	844
Cryolite	7.5	5.4	3.3	5.3	11.1	6.2	1,034
Lead arsenate	7.4	4.3	2.5	4.4	11.8	7.5	1,038
Basic copper arsenate and sulfur 1:1	16.5	5.9	4.0	4.8	11.7	7.2	1,054
Difference required for significance, 5 per cent level		3.8	4.2				181.3

difference in yield between plots treated with calcium arsenate at the rate of 16 pounds per acre and those treated with 1:1 basic copper arsenate and sulfur, the former producing a gain of 397 pounds and the latter a gain of 371 pounds of seed cotton per acre. Plots treated with calcium arsenate at the rate of 12 pounds per acre produced practically the same as those treated with the 1:2 mixture of basic copper arsenate and sulfur—275 and 273 pounds gain, respectively. The plots treated with 8 pounds of calcium arsenate per acre yielded 225 pounds more than the check. The field plot data were analyzed by analysis of variance. Statistically, each insecticidal treatment resulted in a significant gain over the check and the 16-pound treatment of calcium arsenate caused a significantly higher gain than did the 8-pound treatment.

The yield records of experiment 4 show that the 1:1 mixture of basic copper arsenate and sulfur, lead arsenate, and cryolite each resulted in a significantly higher gain than did calcium arsenate. The gain (462 pounds) from 1:1 basic copper arsenate and sulfur was higher, but not significantly higher, than from lead arsenate (446 pounds) or cryolite (442 pounds). The gain from calcium arsenate was only 252 pounds.

SUMMARY.—Field-plot experiments were conducted at Waco, Tex., in 1942 to determine the effectiveness of reduced dosages of calcium arsenate against the boll weevil and whether cryolite could be substituted for calcium arsenate in its control. The comparative effectiveness of calcium arsenate, basic copper arsenate, lead arsenate, and cryolite against the bollworm were also studied.

The boll weevil infestation was too light to show any marked differences in yield between plots treated with calcium arsenate, cryolite, and various dilutions of these materials with sulfur, for weevil control. However, one experiment did show that three dilutions of calcium arsenate reduced the weevil infestation to lower levels (average, 11.9 per cent) than did similar dilutions of cryolite (average, 13.9 per cent).

Eight pounds of calcium arsenate per acre per application failed to control the bollworm, and 16-pound applications resulted in a significantly higher gain in yield (397 pounds per acre) than did 8-pound applications (225 pounds). Basic copper arsenate and sulfur 1:1, applied at the rate of 16 pounds per acre per application (total arsenic pentoxide, 3.1 pounds) resulted in a gain of 371 pounds, or approximately the same as calcium arsenate applied at the rate of 15.8 pounds (total arsenic pentoxide, 6.4 pounds). The 1:2 mixture of basic copper arsenate at the rate of 16 pounds per acre per application (total arsenic pentoxide, 2.1 pounds) was equal to 12.4-pound applications of calcium arsenate (total arsenic pentoxide, 4.8 pounds). Dosages of approximately 8 pounds per acre of basic copper arsenate, lead arsenate, or cryolite resulted in a significantly higher gain in yield than similar dosages of calcium arsenate, the gains being 462, 446, 442, and 252 pounds per acre, respectively.—3-31-43.

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THE AZALEA FLOWER SPOT

The azalea flower spot is the subject of uniform quarantines placed by Oregon and Washington in June 1943 against the States of Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas, and eight southern California counties, requiring certification of azaleas and rhododendrons as to the nursery and the soil in which they were grown.

PHONY PEACH QUARANTINES

The states that have thus far taken action to bring their phony peach quarantines into line with the area described in 1943 standard quarantine pertaining to this disease are Alabama, Georgia, South Carolina, Tennessee and Texas. Of the states infected with the peach mosaic disease only Arizona and California appear to have revised their quarantines to apply to currently infected areas.

Oviposition Habits of the Earworm Moth in Relation to Infestation in the Ears and to Control

G. W. Barber, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In some parts of the northern states where the corn earworm, *Heliothis armigera* (Hbn.), occurs in small numbers, most of the eggs may be deposited on the silks, and many of the ears can be protected by divesting the ears of the silks. Throughout the South during most seasons, and occasionally in the northern states when the insect is abundant, eggs may be deposited on all parts of the plants at all periods of their development, from the time when they are a few inches tall until they ripen. These habits have not been fully described heretofore and the extent of egg deposition on parts of corn plants other than the silk is probably not sufficiently appreciated. As a knowledge of these egg-laying habits is necessary to a thorough understanding of the problem involved in control of the insect, data bearing on this subject have been assembled.

Method of Observation.—During the period 1925 to 1927, inclusive, the oviposition habits of this insect were studied in central Virginia. Plots of field corn of the varieties Reid Yellow Dent and Boone County White were planted at weekly intervals between April 17 and June 26. The numbers of eggs deposited by the earworm moth on several plants of each variety in each plot were recorded daily from time when the plants were a few inches high until the silks had dried. The numbers of eggs deposited on many plants that developed successively throughout the growing seasons of 3 years in two localities were thus observed. From these records the average number of eggs deposited per plant on corn planted at different dates were computed, as summarized in table 1.

Occurrence of Eggs on Field Corn.—According to Dicke (1939), the seasonal abundance of eggs per corn plant is dependent primarily on the acreage of corn attractive to the moths. The number of eggs deposited per plant is high in spring and fall because oviposition is concentrated on comparatively small acreages then available in attractive condition, and low in summer because egg laying is dispersed over a much larger acreage with consequent thinning out, but not actual reduction, of the population. As shown in table 1, the occurrence of eggs per corn plant at Richmond, Va., in 1926 was normal, according to this theory of relationship of corn acreage to egg abundance. The number per plant decreased uniformly in the spring (plantings made on or before May 8) as the acreage of corn in attractive condition increased, and increased uniformly in the fall (plantings made on or after June 5) as the acreage of corn in attractive condition diminished. In 1925 the seasonal occurrence followed this general pattern, but in the fall the number of eggs per plant became very great. This was probably due to continuous dry weather, which favored a high rate of survival and rapid increase in numbers of the insect. In 1927, with the greatest precipitation throughout the growing season of any of the 3 years, the seasonal-occurrence pattern was quite different and the intensity of infestation was unusually low during most of the season, there being no increase in numbers of eggs per plant in the fall. The average number

Table 1.—The average total number of corn earworm eggs deposited per corn plant on 11 weekly plantings, Richmond, Va., 1925–27.

	Average Number of Eggs Deposited per Plant of Corn Planted on—										
	April		May					June			
	17	24	1	8	15	22	29	5	12	19	26
1925	90.8	51.9	49.4	40.8	39.3	53.5	130.1	—	617.4	—	705.6
1926	107.4	45.5	28.7	17.5	14.0	—	19.4	25.8	37.1	—	113.0
1927	71.0	77.2	33.5	18.5	10.2	6.3	7.8	6.8	4.3	2.3	6.5

of eggs recorded per corn plant was 197.6 in 1925, 45.4 in 1926, and 22.2 in 1927. Therefore, during these years the abundance of the insect fluctuated widely, the average number of eggs per plant ranging from 2.3 in the June 19 planting of 1927 to 705.6 in the June 26 planting of 1925.

EGG DEPOSITION ON PLANTS IN VARIOUS STAGES OF GROWTH.—Each year earworm moths appeared early in the season while the plants of the earliest plantings were still small, and eggs were necessarily deposited on the plant parts available—the leaves and stalks. Beginning with the first exposure of silk by the earliest plants, silks were continuously available throughout the season on successive plantings, and during the period July to September it would have been possible for the moths to deposit all their eggs on fresh silks. However, the records given in table 2 show that during the entire period many eggs were laid not only on the silks but also on other parts of the plants, and that they were more widely distributed on the younger plants early in the season than they were on the plants of more advanced growth later in the season.

In the area where these observations were made, corn may be planted commercially over a period of 2 or 3 months; consequently, plants are available in various stages of growth during a considerable part of the summer. Throughout the months June to September, inclusive, moths are present in continuous but varying numbers, and several minor peaks in moth abundance and egg deposition are usually observed within the curve of seasonal abundance as influenced by corn acreage. During these peaks the plants may not always be in the same stage of

Table 2.—Location of corn earworm eggs on plants of Reid Yellow Dent and Boone County White field corn, determined by daily observations from the time the plants were about 6 inches high until after the silks had become brown. Richmond, Va., 1925–27.

	Percentage of the Total Egg Population Deposited on Following Parts of Corn Plants While in Given Stages of Growth										
	Less than 15 Inches			15 Inches to Tassel			Tassel to Silk Moist				
	Leaves			Leaves			Leaves				
Planting Date	Upper Surface	Lower Surface	Total	Upper Surface	Lower Surface	Stalk	Upper Surface	Lower Surface	Stalk	Tassel	Husk
April 17											
1925	1.21	0.55	1.76	5.73	3.19	—	3.86	0.66	1.87	15.86	—
1926	0.93	1.68	2.61	10.43	3.82	0.37	11.92	1.95	7.17	2.05	0.28
1927	3.76	7.28	11.04	17.84	2.35	0.23	23.94	3.29	2.82	10.33	—
April 24											
1925	3.66	1.35	5.01	5.97	3.08	—	7.90	0.96	3.28	17.72	—
1926	0.66	4.83	5.49	25.05	9.45	1.10	22.20	3.08	7.25	4.18	—
1927	4.10	3.67	7.77	16.85	4.53	—	11.23	1.73	4.97	4.32	0.22
May 1											
1925	0.81	1.01	1.82	4.45	1.01	—	5.06	1.01	1.22	14.78	—
1926	3.83	4.18	8.01	33.80	10.45	1.04	17.77	3.83	5.23	1.74	—
1927	1.49	2.98	4.47	28.85	4.48	—	14.93	1.49	2.98	6.96	1.00
May 8											
1925	1.23	0.24	1.47	2.94	0.98	—	6.62	0.49	3.68	25.74	—
1926	1.14	6.86	8.00	38.86	11.43	0.57	7.43	1.71	1.72	—	—
1927	9.01	4.51	13.52	34.24	9.01	—	20.72	5.40	—	9.01	—
May 15											
1925	0.25	—	0.25	8.14	0.51	—	2.04	—	1.27	9.42	—
1926	—	—	—	22.14	2.14	—	4.23	—	—	—	—
1927	3.28	—	3.28	54.10	11.48	—	13.11	—	1.64	—	—
May 22											
1925	0.19	0.19	0.38	3.74	0.75	—	2.61	0.19	0.37	6.92	—
1927	—	2.63	2.63	47.37	10.53	—	10.53	—	—	—	—
May 29											
1925	0.08	0.08	0.16	1.00	0.23	—	1.00	0.61	0.31	1.77	—
1926	0.52	—	0.52	2.06	1.55	—	5.15	1.03	—	—	—
1927	2.13	—	2.13	21.27	8.51	—	2.13	2.13	—	—	—
June 5											
1926	1.16	0.39	1.55	0.39	0.39	—	1.94	0.39	1.16	—	—
1927	—	—	—	9.76	4.88	—	—	—	—	—	—
June 12											
1925	0.02	—	0.02	0.16	0.02	—	0.88	0.23	0.74	2.22	—
1926	0.27	—	0.27	0.54	—	—	2.16	0.54	—	—	—
1927	—	—	—	11.54	—	—	—	—	—	—	—
June 19											
1927	—	—	—	7.14	—	—	—	—	—	—	—
June 26											
1925	—	—	—	0.34	0.11	0.07	1.83	0.64	1.19	5.34	—
1926	—	—	—	0.62	0.09	—	2.66	0.09	0.97	—	0.09
1927	—	—	—	2.56	—	—	2.56	—	—	—	—
All plantings	0.54	0.62	1.16	4.17	1.20	0.08	3.94	0.74	1.63	4.96	0.03

Table 2.—*Continued*

PERCENTAGE OF THE TOTAL EGG POPULATION DEPOSITED ON FOLLOWING PARTS OF CORN PLANTS WHILE IN GIVEN STAGES OF GROWTH

	Silks Moist to Dry						Total Plant				
	Leaves						Leaves				
PLANTING DATE	Upper Surface	Lower Surface	Stalk	Tassel	Husk	Silk	Upper Surface	Lower Surface	Stalk	Tassel	Husk
April 17											
1925	2.86	0.99	2.98	15.53	2.75	41.96	13.66	5.39	4.85	31.39	2.75
1926	14.52	2.05	8.57	3.17	1.95	29.14	37.80	9.50	16.11	5.22	2.23
1927	8.22	0.23	0.70	3.76	1.17	14.08	53.76	13.15	3.75	14.09	1.17
April 24											
1925	5.97	2.12	2.31	13.88	1.16	30.64	23.50	7.51	5.59	31.60	1.16
1926	8.35	0.44	2.64	1.76	0.66	8.35	56.26	17.80	10.99	5.94	0.66
1927	7.78	—	6.05	4.10	1.29	29.16	39.96	9.93	11.02	8.42	1.51
May 1											
1925	4.45	1.62	1.82	11.94	1.82	49.00	14.77	4.65	3.04	26.72	1.82
1926	4.18	1.40	—	—	0.35	12.20	59.58	19.86	6.27	1.74	0.35
1927	4.98	0.50	0.50	0.50	1.99	26.37	50.25	9.45	3.48	7.46	2.99
May 8											
1925	3.43	1.23	1.47	13.23	0.73	37.99	14.22	2.94	5.15	38.97	0.73
1926	8.00	—	0.57	—	1.71	20.00	55.43	20.00	2.86	—	1.71
1927	0.90	—	0.90	—	0.90	5.40	64.87	18.92	0.90	9.01	0.90
May 15											
1925	4.07	2.54	1.78	24.18	1.02	44.78	14.50	3.05	3.05	33.60	1.02
1926	16.43	3.58	4.28	—	2.86	44.29	42.85	5.72	4.28	—	2.86
1927	—	—	—	—	1.64	14.75	70.49	11.48	1.64	—	1.64
May 22											
1925	10.84	3.55	1.87	25.79	2.06	40.93	17.38	4.68	2.24	32.71	2.06
1927	7.89	—	—	—	—	21.05	65.79	13.16	—	—	—
May 29											
1925	9.76	2.92	4.15	31.36	2.38	44.35	11.84	3.84	4.46	33.13	2.38
1926	23.71	2.57	3.61	—	0.52	58.25	31.44	5.15	4.64	—	0.52
1927	8.51	—	—	—	—	55.32	34.04	10.64	—	—	—
June 5											
1926	16.28	3.48	4.65	0.39	3.88	65.50	19.77	4.65	5.81	0.39	3.88
1927	14.63	2.44	—	—	9.76	58.53	24.39	7.32	—	—	9.76
June 12											
1925	9.02	3.43	5.33	28.44	3.69	45.82	10.08	3.68	6.07	30.66	3.69
1926	10.78	1.89	3.23	0.54	3.23	76.82	13.75	2.43	3.23	0.54	3.23
1927	11.54	—	—	—	—	76.92	23.08	—	—	—	—
June 19											
1927	21.43	7.14	—	—	7.14	57.15	28.57	7.14	—	—	7.14
June 26											
1925	7.95	2.66	7.27	36.24	3.96	32.40	10.12	3.41	8.53	41.58	3.96
1926	13.01	1.60	7.07	1.24	4.60	67.96	16.29	1.78	8.04	1.24	4.69
1927	17.96	2.56	—	—	2.56	71.80	23.08	2.56	—	—	2.56
All plantings	8.73	2.48	5.24	23.03	3.11	39.50	17.38	5.04	6.95	27.99	3.14

maturity. If the moths happen to be particularly abundant before rather than during the period when silks are exposed, the heaviest oviposition may occur on parts of the plants other than the silks. These variations in abundance of eggs within the larger seasonal fluctuation due to acreage of corn most attractive to the ovipositing moths, and the varied stages of maturity of the plants at the time of these high levels of moth abundance, are two reasons why earworm eggs are so widely distributed on the plants. Of the 246 plants observed, only 2.44 per cent bore eggs exclusively on the silks, 89.43 per cent bore eggs on silks and on other plant parts, and 8.13 per cent bore eggs only on other parts than the silks. All the plants received eggs during some period in their development. In general, as indicated by the data in table 3, eggs are apparently deposited on all parts of the corn plant in all stages of its development during most of the growing season.

Observations of successive plantings of sweet corn in 2 years showed wide distribution of eggs on all parts of the plants while they were in several stages of growth, similar to that observed on field corn, as shown in table 4.

Since the numbers of eggs deposited on corn plants in different years or in different seasons of the same year varied, it was possible to determine whether the level of population affected the distribution of eggs on different parts of the plants. For the purpose of this study the data taken at Richmond and Charlottesville, Va., for 1925 to 1927, inclusive, were available. All parts of the plants to be mentioned were available following the exposure of the earliest silks of the first plantings; therefore, except for the period before exposure of the first silks, the moths

Table 3.—Occurrence of corn earworm eggs on plants of field corn while in several stages of growth, Richmond, Va., 1925–27.

Planting Date	Number of Plants	Percentage of Plants on which Eggs Were Deposited While in the Following Stages of Growth			
		Less than 15 Inches	15 Inches to Tassel	Tassel to Silk Moist	Silk Moist to Dry
April					
17	26	88.46	96.15	100.00	100.00
24	26	88.46	100.00	100.00	92.31
May					
1	26	76.92	92.31	100.00	96.15
8	26	61.54	88.46	88.46	96.15
15	26	11.54	92.31	65.38	88.46
22	16	18.75	81.25	81.25	93.75
29	26	15.38	65.38	57.69	100.00
June					
5	16	37.50	31.25	25.00	100.00
12	26	7.69	34.61	65.38	100.00
19	6	0	16.67	0	100.00
26	26	0	34.46	73.08	100.00
Total	246	40.65	73.98	75.65	96.75

could choose for oviposition any desired plant parts. The numbers and percentages of eggs found on 436 corn plants, planted on 11 dates in the 2 localities during the 3 years, are given in table. 5. This arrangement of the data indicates that, irrespective of population levels of the eggs, the percentages deposited on the husks and silks remained about the same. On the other hand, as population levels were higher, fewer eggs were deposited on the leaves, but proportionately more were deposited on the stalks and tassels. The percentages of plants that received eggs on their various parts at different population levels are given in table 6. These data show that the tendency to deposit eggs on all parts of the plants increased with the rise of the population level.

EARS ATTACKED BY LARVAE NOT HATCHED ON SILKS.—The wide distribution of earworm eggs on different parts of corn plants during different stages of growth results in the presence of larvae on different parts of the plants over a protracted period. Probably many of these larvae fail to survive because they do not find favorable feeding places or suitable food, but some of them reach the whorl, where they feed on the tender unrolled leaves or penetrate to the tassel as soon as it begins to develop. They remain in the tassel until it becomes exposed and no longer affords protection, then migrate to the ear, which by that time is beginning to expose silk. Such migrants may be found in or entering the ears almost immediately after the silks have been exposed.

On April 14, 1936, at Homestead, Fla., 250 ears of Snowflake corn having unwilted silk, which had been exposed less than 1 day, were examined. Partly grown earworms were found to be entering 62.4 per cent of these ears and were feeding, usually being partly exposed in the silk. The amount of their feeding indicated that they had reached the ears recently. Of the total number of ears examined, 57.6 per cent contained a single larva, 4.0 per cent contained 2 larvae, 0.4 per cent contained 3, and 0.4 per cent contained 4. In the total number of ears 171 larvae were recovered, 0.58 per cent of which were second instars, 29.24 per cent were third, 48.54 per cent were fourth, 18.71 per cent

Table 4.—Earworm eggs deposited on different parts of sweet corn plants planted on various dates at Charlottesville, Va., 1926 and 1927.

Planting Date	Number of Plants	Total Number of Eggs Observed	Average Eggs per Plant	Percentage of Egg Population Deposited on the Following Plant Parts					
				Leaves		Stalks	Tassels	Husks	Silks
				Upper Surface	Lower Surface				
March 30	6[1]	1,263	210.5	14.81	2.61	14.09	12.67	8.47	47.35
April 28	6[1]	711	118.4	18.00	3.38	10.41	13.78	2.25	52.18
May 12	6[1]	411	68.5	8.52	4.38	5.59	13.38	1.95	66.18
May 23	6[1]	80	13.3	15.00	3.75	12.50	2.50	3.75	62.50
June 6	6[1]	181	30.3	9.39	1.10	1.66	1.66	3.32	82.87
June 14	6[1]	216	36.0	7.87	0	.92	.92	5.56	84.73
June 23	6[1]	455	75.8	10.33	.66	2.20	1.54	14.29	70.98
July 2	3[2]	267	89.0	1.12	0	0	.38	10.49	88.01
July 9	3[2]	100	33.3	1.00	0	13.00	0	10.00	76.00
All plantings	48	3,684	76.7	12.13	2.25	8.50	8.90	6.92	61.30

[1] Records for 1926 and 1927.
[2] Records for 1927.

Table 5.—Location of corn earworm eggs on different parts of field-corn plants that received various egg populations at Richmond and Charlottesville, Va., 1925–27.

Number of Eggs per Plant	Number of Plants Observed	Total Number of Eggs Observed	Percentage of Egg Population Deposited on the Following Plant Parts					
			Leaves					
			Upper Surface	Lower Surface	Stalks	Tassels	Husks	Silks
1–5	77	254	36.22	8.27	3.54	1.18	3.94	46.85
6–10	58	447	37.36	9.84	3.13	2.24	2.91	44.52
11–25	96	1,659	32.67	9.35	3.32	5.30	2.71	46.65
26–50	87	3,294	27.69	5.92	5.86	14.63	2.34	43.56
51–100	64	4,632	23.40	5.46	7.12	16.75	3.26	44.01
101–250	32	4,611	15.70	3.34	9.87	11.78	3.60	55.71
251–500	5	1,677	19.86	3.69	13.60	25.52	2.15	35.18
501–1,000	17	12,192	9.47	3.44	6.78	36.83	3.99	39.49
All levels of population	436	28,766	17.41	4.53	7.34	23.71	3.42	43.59

were fifth, and 2.92 per cent were sixth. All these larvae had migrated to the ears from other parts of the plants, usually from the tassels. Of 100 partly exposed tassels examined on the given date, 32 per cent contained a single larva each and 5 per cent contained 2 larvae each. A total of 42 individuals were found in the tassels, of which 4.76 per cent were third instars, 23.81 per cent were fourth, 42.86 per cent were fifth, and 28.57 per cent were sixth. At the time the tassels were examined birds were feeding on the larvae, which is probably one reason why fewer larvae were found in the tassels than in the ears.

In an examination in Dade County, Fla., in March 1939, of 25 ears of Golden Cross Bantam sweet corn having fresh silks, all but 3 contained earworms. The largest number of larvae found per ear was 8, and 77 larvae, or an average of 3.1 per ear, were found. Of these larvae 67.5 per cent were first instars, 27.3 per cent were second, and 5.2 per cent were third. These silks had been exposed for not more than 1 day, therefore all the larvae found on them had hatched on other parts of the plants.

RELATION OF EGG-LAYING HABITS TO CONTROL.—The observations that have been described, as well as many others, show that earworm eggs may be deposited not only on the silks but also on all other parts of corn plants at any time during the period when they are growing and are green. It seems probable, therefore, that, under most conditions within the range where this insect is abundant, partly grown larvae are present on the plants before the silks are exposed and many of

Table 6.—Eggs deposited on different parts of field-corn plants at various population levels at Richmond and Charlottesville, Va., 1925–27.

Number of Eggs per Plant	Number of Plants Observed	Percentage of Plants that Received Eggs on the Following Parts						Mean Percentage of Plant Parts on Which Eggs Were Deposited
		Leaves						
		Upper Surface	Lower Surface	Stalks	Tassels	Husks	Silks	
1–5	77	59.7	23.4	9.1	2.6	13.0	75.3	30.5
6–10	58	75.9	44.8	17.2	10.3	17.2	82.8	41.4
11–25	96	89.6	58.3	39.6	28.1	27.1	92.8	55.9
26–50	87	96.5	65.5	67.8	62.1	45.9	94.3	72.0
51–100	64	100.0	79.7	87.5	89.1	70.3	100.0	87.8
101–250	32	100.0	87.5	96.9	84.4	96.9	100.0	94.3
251–500	5	100.0	100.0	100.0	100.0	100.0	100.0	100.0
501–1,000	17	100.0	100.0	100.0	100.0	100.0	100.0	100.0
All levels of population	436	86.7	59.2	51.1	44.7	42.2	90.8	62.5

them migrate to the ears, beginning immediately after silk exposure. During the time that the ears are developing, larvae are moving to them, not only from eggs placed on the silks but also from eggs placed on other parts of the plants, in numbers somewhat proportionate to the egg population. Although most of these larvae perish in the ears through cannibalism when they are concentrated in the interior silk above the kernels, the success of control measures is affected by the egg-laying and larval-migration habits that have been described. If insecticidal dusts or sprays are placed on the exterior silks, larvae probably will have previously penetrated into the interior silks of the ears, so that, even if all further entrance of larvae into the ears is prevented, control will not be obtained. If the exterior silk is removed from the ears before the eggs that have been deposited thereon have hatched, and even if the husk tips bearing eggs and larvae are cut from the ears, larvae from other parts of the plants will probably enter the ear tips almost immediately thereafter.

RELATION OF NUMBER OF EGGS DEPOSITED TO NUMBER OF KERNELS INJURED.—It has sometimes been assumed that because of the highly developed cannibalistic habits of the corn earworm the amount of damage done to corn ears is not correlated directly with egg populations on the plants. However, since no data bearing on this subject have been published, the following observations may be of interest: In the studies of oviposition in field corn at Richmond, Va., in 1926 and 1927, and at Charlottesville, Va., in 1927, records were taken of the number of kernels destroyed by earworms in ears of the plants observed. A comparison can therefore be made to determine whether the extent of kernel injury was correlated with the number of eggs deposited on the plants. The total number of plants involved was 210, on 207 of which ears developed normally. A summary of the data obtained is given in table 7.

In relation to the number of eggs deposited on the entire plants, the average number of kernels injured per ear increased up to populations of 20 eggs per plant; at populations of from 21 to 100 eggs per plant there was so significant difference in number of kernels injured per ear, but populations of more than 100 eggs per plant were accompanied by increased kernel injury per ear. Therefore except for the extremes of very few or very many eggs deposited per plant, the extent of kernel injury per ear was not correlated with egg population deposited on the plant. On the other hand, the number of kernels injured per egg deposited on the entire plant decreased regularly in proportion as egg populations were greater. This probably indicates that eggs were destroyed by parasites and predators and larvae were destroyed by cannibalism in larger numbers in proportion as populations were greater. The kernel injury to ears of plants on which no eggs were found probably may be attributed to migratory larvae.

The average total number of eggs de-

Table 7.—Comparison of the number of kernels injured per ear with the population of corn earworm eggs deposited on corn plants or on the silks, Richmond, Va., 1926–27, and Charlottesville, Va., 1927.

Number of Eggs per Plant	Eggs Laid on Entire Plants				Eggs Laid on Silks Only				
	Number of Ears	Percentage of Ears Injured[1]	Average Number of Kernels Injured		Number of Eggs per Silk	Number of Ears	Percentage of Ears Injured[1]	Average Number of Kernels Injured	
			Per Ear	Per Egg				Per Ear	Per Egg
0	4	50.0	10.1	—	0	29	65.5	22.3	—
1–10	72	76.4	30.5	5.6	1–5	92	78.3	34.2	12.9
11–20	43	86.0	44.7	3.0	6–10	28	78.6	32.4	4.3
21–30	27	85.2	50.9	2.5	11–15	12	100.0	58.2	4.2
31–40	14	78.6	48.8	1.4	16–20	13	92.3	64.8	3.7
41–50	11	72.7	46.3	1.0	21–25	5	80.0	72.8	3.2
51–100	21	85.7	53.4	.7	26–50	15	100.0	73.9	2.2
Over 100	15	100.0	67.2	.5	51–75	4	100.0	62.5	0.9
					76–100	7	100.0	59.0	0.7

[1] Ears counted as injured were those in which kernels had been devoured.

posited on the entire plants and on the silks alone was 29.6 and 12.6, respectively. Thus 42.4 per cent were deposited on the silks. In relation to the number of eggs deposited on the silks alone, the data show that the average number of kernels injured per ear increased roughly in proportion as the number of eggs per silk was greater. Nevertheless, the number of kernels injured per egg deposited on silks decreased regularly as the number of eggs per silk was greater, indicating again the probability that as egg populations were greater their enemies and cannibalism among the larvae were more effective in limiting survival.

As may be seen from table 7, approximately two-thirds of the ears of plants on which no eggs were deposited on the silks were injured, indicating that larvae reached the ears after hatching from eggs deposited on other locations on the plants.

NATURAL ENEMIES IN RELATION TO EGG POPULATIONS.—In a previous paper (Barber, 1936) the writer described field observations on parasitization of earworm eggs by *Trichogramma minutum* Riley, from which the conclusion was drawn that the parasite attained its greatest effectiveness when host eggs were most abundant. Although this conclusion was based on limited observations, data were available from the studies described herein for use in further exploring the subject.

The eggs deposited on 1 plant of each plot were marked and their fate was determined. From these observations, records of the fate of eggs found on 1 plant in each of 94 plots planted at Richmond, Va., in 1925, 1926, and 1927, and at Charlottesville, Va., in 1926 and 1927 were available for study. On these plants a total of 4744 eggs were deposited, but the fate of only 41.8 per cent was determined with certainty, principally because the remainder were dislodged from the plants or otherwise lost. Only the eggs of known fate were used in the present study, which includes those that hatched, those parasitized by *Trichogramma*, and those devoured by (*Triphleps*) *Orius insidiosus* (Say). No eggs of known fate were recovered on 7 plants. Hence the data available for study consisted of records of the fate of 1982 eggs deposited on 87 plants.

Orius devours eggs in all stages of development, from those recently deposited to those from which larvae are hatching, and also attacks eggs in all stages of parasitization as well. Consequently it would appear at first that much overlapping of feeding by *Orius* and by *Trichogramma* would result. Actually such interference is limited, because these enemies have their peculiar spheres of influence on the corn plant, as their habits are different. *Orius* inhabits silks particularly, in the strands of which it deposits its eggs and among which the nymphs and adults hide and feed; therefore this predator devours a greater proportion of eggs deposited on silks than of those deposited on other parts of the plant. *Trichogramma* appears to dislike the corn-silk environment, possibly because the very abundant setae of the silk limit its activities; consequently this parasite attacks a larger proportion of the eggs deposited on the leaves than of those deposited on the silks.

Table 8.—Relationship of populations of corn earworm eggs deposited on corn plants to the percentage parasitized by *Trichogramma minutum* or devoured by *Orius insidiosus*.

Number of Eggs per Plant	Number of Plants	Total Number of Eggs	Percentage of Earworm Eggs		
			Parasitized by *Trichogramma*	Devoured by *Orius*	Hatched
1 to 25	65	670	16.9	37.8	45.3
26 to 50	13	465	23.4	46.0	30.6
51 to 75	3	186	32.3	51.6	16.1
75 to 100	3	248	38.7	48.0	13.3
Over 100	3	413	35.8	54.2	10.0

The results of a study of the data are summarized in table 8. It was found that, in general, the percentages of host eggs destroyed by *Trichogramma* and *Orius* increased as populations of the eggs were greater. These enemies seem to have been increasingly effective up to populations of about 100 eggs per plant in the case of *Trichogramma* and about 75 eggs per plant in the case of *Orius*, but in larger populations of eggs the increase in effectiveness was less significant or ceased entirely. The data suggest that a point may be reached when host eggs are deposited at a rate with which the enemies cannot cope immediately—for example, when the moths suddenly become very abundant, with resulting abrupt and rapid increase in the number of eggs deposited. Apparently such instances are relatively rare, however, because only 10.3 per cent of the observed plants car-

ried more than 50 host eggs per plant.

A further analysis of the data also seems to show that *Trichogramma* was proportionately more effective as egg populations were greater. When the data were tabulated according to planting dates, it was found that the rate of parasitization was greatest in early and in late plantings, when host eggs were most abundant. per plant and least in mid-season plantings, when eggs were least abundant. Thus of 26 plants of 3 early-planting dates, which bore eggs at an average rate of 28.2 per plant, the average rate of parasitization was 33.7 per cent. Of 46 plants of 5 midseason planting dates, which bore eggs at an average rate of 9.7 per plant, the average rate of parasitization was 22.9 per cent. Of 22 plants of 3 late-planting dates, which bore eggs at an average rate of 36.7 per plant, the average rate of parasitization was 30.4 per cent. These data do not mean that either the host eggs or the parasites were less numerous in midsummer; on the contrary, the populations of each probably increased regularly during the entire season, but were dispersed in such large acreages that the numbers per plant were smaller than in spring and fall, when the populations were concentrated in small acreages. The data do indicate that when the host eggs were dispersed in large acreages and there were fewer per plant, the parasites were able to find relatively fewer eggs and the percentage of parasitization was lowest. In spring and fall, when eggs were concentrated in small acreages and closer together on an average the parasites could find relatively more, and the percentage of parasitization was highest.

SUMMARY.—Records of egg laying by moths of the corn earworm, *Heliothis armigera* (Hbn.), obtained in central Virginia during 1925 to 1927, inclusive, showed that eggs were deposited on all parts of corn plants during all stages of their growth. This was true for both field corn and sweet corn. It was also true in general regardless of the population levels of the eggs.

The larvae that hatch from eggs laid on plants before the silks are exposed feed on whatever parts of the plants may be most attractive at the time of hatching, the most suitable of which are the tender leaves of the whorl and the green tassel. Such larvae begin to migrate to the silks of the ears almost immediately after silk exposure, and they may enter many ears before dusts or sprays could be applied. These larvae may migrate to the ears over a period of several days and they offer one of the greatest difficulties in the control of the insect in the ears.

When earworm eggs are laid abundantly or indiscriminatively, as described, such proposed control measures as removing the silks or clipping the tip of the husks from the ears are ineffective because migrating larvae reinfest the ears almost at once.

A comparison of the number of kernels injured in ears of plants on which varying numbers of earworm eggs were laid showed that, although the extent of kernel injury was not closely correlated with the number of eggs deposited on the entire plant, it was correlated with the number of eggs deposited on the silks.

A study of the percentages of egg populations destroyed by *Trichogramma minutum* Riley and *Orius insidiosus* (Say) showed that, in general, the efficiency of each of these enemies increased in proportion as populations of host eggs were greater—2-7-43.

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Some Chemotropic Studies with *Autographa* spp.[1]

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The cabbage looper, *Autographa brassicae* (Riley), and the tomato fruitworm, *Heliothis armigera* (Hbn.), are important economic pests of vegetable crops in the South. In 1926, during field control studies of the tomato fruitworm at Baton Rouge, La., the writers initiated experiments directed at the development of a method whereby the moths could be destroyed before they laid their eggs. The experiments consisted essentially in catching the moths by means of light traps, baited pans, and chemically baited trap cages. The experiments were continued seasonally for 5 years and, although no good attractant for the tomato fruitworm was found, the moths of the cabbage looper and several closely related species were rather strongly attracted to several chemicals, or to impurities contained in them.

PRELIMINARY EXPERIMENTS.—In 1926 the following substances were exposed in saucepans in infested fields: (1) Sweet solutions, fermented and unfermented; (2) extracts and distillates of several plants and flowers on which the moths had been observed to feed and oviposit; and (3) a few aromatic chemicals. At the same time various colored lights were compared for their attractiveness to the moths. The light tests were conducted in the presence of an exceptionally heavy population of tomato fruitworm moths and during dark nights when conditions were favorable for flight. Not enough of these moths were collected in either the bait pans or the light traps to be of economic importance, although a fairly large number of other species of insects were attracted. It was therefore considered advisable to test various chemicals having distinct odors as possible attractants. For this purpose it was necessary to devise a trap cage.

For trapping the cabbage looper moth and related species, a cage 36 inches high and 16 inches square was found satisfactory. It was constructed of 1×1 inch wooden strips and window screening, and consisted of two sections. The top section was 12 inches deep and was enclosed on all 6 sides, but with a hinged door on one side to permit access to the interior. The bottom was convexed upward and contained an opening in the center 6 inches in diameter to permit the entrance of the moths. The lower section was 15 inches deep, and the screening on all four sides was bent gradually inward and upward from the bottom to form open channels that led to and ended just below the opening to the top section, or receiving compartment. The cages were baited by applying the undiluted chemical to a small sponge fastened within a waxed-paper cone, which was hung in the lower section of the cage. The chemical was renewed every 7 days by adding a few drops to the sponge.

TRAP-CAGE EXPERIMENTS PRIOR TO 1930.—During 1927–29 investigations were confined largely to testing chemicals of commerical purity. More than 500 substances, mostly aromatic chemicals, were exposed in trap cages for 2 or 3 weeks, and then the more promising materials were used in additional tests and repeatedly compared.

Fields of growing cabbage, carefully selected with regard to size, location, environment, and prevailing looper population, were used for the tests. The cages were usually placed near the edges of the field and about equidistant from each other. To lessen further the chances of inequality, the cages of a series were moved around the field, each being advanced a position in the same direction from day to day. Even with these precautions environmental factors, especially wind direction, very likely had some effect on the results.

The cages were usually visited daily except Sunday, and the moths caught were removed. The important insects were segregated by species and sex. The

[1] This work was done in cooperation with the Louisiana Agricultural Experiment Station. Publication of these results has been withheld pending the accumulation of more data, but there has been no opportunity to continue these studies. Since the war has brought the need for control methods to supplement the use of insecticides, it appears desirable to publish this work, which may furnish some leads for further studies of insect baiting and trapping.

[2] At the time this work was done Dr. Nelson was a chemist in the U. S. Department of Agriculture; he resigned October 26, 1942.

Table 1.—Attraction of moths of *Autographa* spp. to cages containing various chemicals and their distillation fractions, 1930.

Chemicals and Their Fractions[1]	Moths Collected[2]	
	Both Sexes	Females
Benzyl isovalerate:	*Number*	*Number*
Original	47	25
70°–90° F., 3.5 mm.	61	26
90°–98° F., 3.5 mm.	16	13
98°–101° F., 4.0 mm.[3]	13	6
Check	0	0
Benzyl ether:		
Original	62	24
105°–113° F., 2.5 mm.	124	65
113°–115° F., 2.5 mm.[3]	170	65
115°–140° F., 2.5 mm.	69	30
Residue, 140° F. up, 2.5 mm.	24	10
Check	0	0
Diphenyl ether:		
Original	75	30
90°–112° F., 3.5 mm.	7	4
112°–113° F., 3.0 mm.[3]	44	19
Residue, 113° F. up, 3.0 mm.	4	2
Check	0	0
Palmitaldehyde:		
Original	7	4
98°–128° F., 2.5 mm.	90	38
128°–131° F., 2.0 mm.[3]	74	30
131°–145° F., 2.0 mm.	40	20
Residue, 145° F. up, 2.0 mm.	41	26
Check	0	0
Benzyl acetate:		
Original	331	140
63°–82° F., 5.0 mm.	145	76
82°–85° F., 4.0 mm.[3]	90	41
Residue, 85° F. up, 4.0 mm.	453	224
Check	4	2
Phenylacetaldehyde:		
Original	233	120
73°–78° F., 3.5 mm.	58	28
78°–81° F., 3.0 mm.[3]	599	290
Residue, 81° F. up, 3.0 mm.	2	1
Check	0	0
Total	2883	1359

[1] The fractions are designated by the temperature range and pressure at which they distilled.

[2] The moths were collected by the different chemicals during the following periods: Benzyl isovalerate Oct. 3–24, diphenyl ether Oct. 13–27, all others Oct. 15–Nov. 4.

[3] Purest fraction of chemical.

females were then dissected to determine the stage of egg development.

The looper moths were first found to be strongly attracted to diphenyl ether in 1927. In the spring of 1928 benzyl ether phenylacetaldehyde, and palmitaldehyde were also found to be attractive to these moths. Therefore, during the fall of 1928 all four materials were tested competitively. Benzyl ether, phenylacetaldehyde, and palmitaldehyde were similar in attractiveness, but only about one-fourth as many moths were caught in the diphenyl ether cages.

In 1929 benzyl acetate and benzyl valerate were tested in addition to the materials used the previous year, and the tests were made on farms several miles apart. Phenylacetaldehyde was much superior to all the other chemicals. Benzyl acetate showed some promise, although it attracted less than half as many moths as phenylacetaldehyde. Palmitaldehyde, diphenyl ether, and benzyl valerate ranked about the same, each catching less than 18 per cent as many moths as the phenylacetaldehyde.

The results obtained in 1928 and 1929 showed that the relative attractiveness of the same chemicals varied considerably in different series, or in different years. For example, in 1928 phenylacetaldehyde, benzyl ether, and palmitaldehyde were about equal in attractiveness, whereas in 1929 phenylacetaldehyde was much superior to the other two. Since the materials were obtained from different manufacturers, or from different lots from the same manufacturer, it was thought that some of the variations might be due to impurities in the chemicals. Consequently, samples of the chemicals were subjected to analysis. Refractive indices and boiling points showed that none of the chemicals were pure, and some were very impure, although most of them were of the purest grade obtainable commercially.

TESTS IN 1930.—Owing to the possibility that some foreign substance or some fraction of the commerical product might be the real attracting agent and that this might vary in amount in different lots, even from the same manufacturer, an effort was made to obtain chemically pure samples of the most promising chemicals for testing in 1930. As these were not available commercially J. L. E. Erickson, of Louisiana State University, undertook the fractionation of available materials.

Six locations were chosen, at each of which one cage was baited with an undiluted commercial chemical and other cages with a distillation fraction of that chemical. An unbaited check cage was also used at each location. Although some competition prevailed between some of the locations, it did not exist throughout the experiments. Moreover, exposures to unequal moth populations doubtless prevailed between the different locations. Neither were all the chemicals under test

at the same time, or for equal periods Therefore, to give each chemical as fair representation as possible, only the moths caught during nearly equal periods are included in table 1. In most cases this does not represent the entire period during which the series was in operation.

It will be seen from table 1 that none of the chemicals or their fractions attracted a large number of moths. This was due, at least in part, to the scarcity of looper moths in 1930. In the benzyl acetate series it is evident that the attracting substance is not the pure ester but a foreign substance which is most concentrated in the residue. In the phenylacetaldehyde series the indications are that the attracting agent is the purest fraction or a foreign substance having the same boiling range.

Of the total number of moths caught nearly half were females. The dissection records showed that most of the females contained large numbers of eggs in all stages of development. Only an occasional moth was found that appeared to be about spent, and a larger number had not begun to lay eggs.

The tests showed that phenylacetaldehyde was the most effective material. Because commercail phenylacetaldehyde crystallizes on standing, especially at low temperatures, and further to obtain a cheaper attractant, dilutions of this material in three solvents, ethyl alcohol, diethyl phthalate, and a proprietary solvent called *Glycyl*, were tested for a short time. All the solvents prevented crystallization, but alochol and *Glycyl* reduced the attractiveness. A 10 per cent solution of the phenylacetaldehyde in *Glycyl* caught about half as many moths as the undiluted commercial chemical, but a similar strength in diethyl phthalate caught as many moths as the undiluted chemical.

While a large percentage of the looper moths caught in these experiments were *Autographa brassicae*, considerable numbers of several other species, namely, *A. oo* (Cram.), *A. oxygramma* (Geyer), *A. ou* (Guen.), *A. verruca* (F.), *A. basigera* (Walk.), *A. biloba* (Steph.), and several undetermined species, were also caught. It is emphasized that the numbers of looper moths shown in table 1 represent only a small percentage of the total number of this group of moths that were collected during the five seasons when the studies were made.

OTHER CHEMICALS ATTRACTIVE TO LOOPER MOTHS.—Several other chemicals also attracted the looper moths to a lesser degree. These included benzyl alcohol, n-butyl n-butyrate, isobutyl salicylate, d-bornyl acetate, cinnamyl acetate, ethylene glycol diacetate, o-nitrotoluene, phenylbutyl aldehyde, phenylglycol acetate, isoamyl salicylate, myristaldehyde, salicylaldehyde, sodium lactate, essence of black currant, artificial grape flavor, oil of petitgrain, oil of cedar leaf, oil of bois de rose, oleoresin capsicum, and Violone Alpha (synthetic violet).

SUMMARY.—In experiments conducted at Baton Rouge, La., 1926–30, light traps, bait pans, and more than 500 compounds, most aromatic chemicals, exposed in trap cages, were tested as possible means whereby the moths of the tomato fruitworm, *Heliothis armigera* (Hbn.), and the cabbage looper, *Autographa brassica* (Riley), could be destroyed before they laid their eggs. The tests were largely negative for the tomato fruitworm, but several of the chemicals strongly attracted the cabbage looper and several closely related species when exposed in suitable trap cages.

The most attractive chemicals were phenylacetaldehyde, benzyl ether, benzyl acetate, palmitaldehyde, diphenyl ether, and benzyl valerate. However, in tests comparing the original and three or four distillation fractions, including the residue, the purest fractions were most attractive only of benzyl ether and phenylacetaldehyde. Of the other chemicals, the original of diphenyl ether, first fractions of benzyl isovalerate and palmitaldehyde, and the residue of benzyl acetate were most attractive. Several other chemicals, or impurities contained therein, were slightly attractive to the looper group of moths.

A 10 per cent solution of phenylacetaldehyde in diethyl phthalate caught as many moths as the undiluted chemical, but similar solutions in ethyl alcohol and *Glycyl* were less attractive.

Approximately half of the looper moths collected in the chemically baited cages were females, and a large percentage of these were gravid.—4-19-43.

The Effect of Tobacco Plant-Bed Construction on the Development of Flea Beetle Populations[1]

CLEMENCE LEVIN, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The control of the tobacco flea beetle, *Epitrix parvula* (F.), in tobacco plant beds is considered one of the most important steps tobacco growers can utilize in the general control of this pest. Metcalf & Underhill (1919) stated that control of the tobacco flea beetle in a plant bed results in two important accomplishments: "(1) It insures a crop of good strong plants, and (2) it destroys the beetles so that they cannot attack the plant later in the field." In 1939 the potential importance of tobacco plant beds as breeding places for the beetle was demonstrated by the author (1940). The moist, sheltered beds with tender plants furnish excellent conditions for flea beetle development. The accessibility to a plant bed largely determines the size of the population which develops.

Three types of plant-bed construction are commonly used by tobacco growers in North Carolina, namely, (1) open type, with no side walls and the cloth cover pegged down at the sides, (2) pole type, with side walls of pine logs to which the cloth cover is attached, and (3) closed type, with side walls constructed of boards set on edge and embedded about 2 inches in the soil and nailed together tightly, and the cloth cover drawn over the top edges of the boards and attached to the sides.

To study the comparative effectiveness of these types of plant-bed construction in preventing the entrance of flea beetles, experimental beds representing the three types were kept under close observation during the seasons of 1940 and 1942. The comparison was made mainly on the basis of the populations of adults developing in the different beds.

EXPERIMENTAL PROCEDURE.—In 1940 the beds were all situated in one location and there were two replicates for each of the three types. In 1942 three replicates were used, and each replicate was situated in a different location. The sites for the beds were prepared and sowed in the manner generally employed in the area. Before time for the emergence of the spring brood of adults, soil samples were taken in order to determine the stage of development of the beetles and the probable date of emergence. Shortly before emergence might be expected five cylindrical cages were placed at random in each bed. These cages were steel frames covered with cloth, and each occupied an area of 1 square foot of soil surface. Before the cages were set in place the tops of all plants under each cage site except one or two were cut about 3/4 inch above the ground in such a way that the root systems of the plants would not be disturbed. After the cages were securely in place and well banked with soil, the interiors were dusted with 1 per cent rotenone dust to kill any overwintering beetles that might be present.

All cages were examined at intervals of 2 days, at which times the beetles present were collected by means of a suction collecting machine. The collections were made over a period of 30 days. By this method population records from five 1-square-foot sampling units in each bed were obtained.

RESULTS.—The records of the collections as presented in table 1 show the average number of beetles emerging per square foot from each type of plant bed as well as the trend of this emergence.

Table 1.—The average number of tobacco flea beetles that emerged per square foot of each type of tobacco plant bed. Oxford, N. C., 1940 and 1942.

	1940				1942		
	Type of Plant Bed				Type of Plant Bed		
Date	Open	Pole	Closed	Date	Open	Pole	Closed
June				May			
4	0.1	0.2	0	22	1.13	0	0
6	0.6	1.0	0	23	2.86	0.06	0
8	2.2	3.4	0.2	25	9.86	1.33	0.13
10	4.7	10.4	0.5	27	13.13	3.26	0.06
12	10.5	19.4	1.0	29	20.93	7.06	0.06
14	15.9	32.5	0.3	June			
16	26.5	15.8	0.7	1	48.46	25.20	0.60
18	23.9	16.1	1.0	3	35.20	17.66	1.60
20	20.4	13.1	2.1	5	31.06	28.46	7.33
22	14.5	15.4	3.2	8	18.73	27.06	11.20
24	14.2	11.0	5.5	10	9.20	15.00	5.13
26	9.5	13.0	9.5	12	7.33	11.53	5.80
28	7.9	9.6	7.7	15	7.00	10.66	8.80
30	7.4	8.0	7.0	17	4.00	6.13	6.80
July				19	2.46	3.86	4.66
3	3.8	5.5	3.7	22	1.53	2.73	3.80
All dates	162.1	174.4	42.4	All dates	212.88	160.00	55.97

[1] Paper prepared for the COTTON STATES BRANCH Program for 1943.

The fact that emergence in the open-type beds began sooner than in the closed type indicated the difficulty the beetles encountered in entering the latter. The peak of emergence was reached approximately 2 weeks after emergence began.

The average number of flea beetles recovered per square foot from the closed pole, and open beds were 50, 176, and 193, respectively. An analysis of variance showed that significantly fewer flea beetles emerged from the closed type of bed than from either the pole type or the open type. There was no appreciable difference in the emergence of the latter two types.

DISCUSSION.—There is great variation in the construction of pole-type beds, particularly in so far as their effectiveness in excluding flea beetles is concerned. In the experiments an attempt was made to construct what might be termed an average pole bed, neither very tightly nor very loosely put together. It is evident that a pole bed, unless carefully constructed, is little if any more effective in excluding flea beetles than an open-type bed. The results of the experiment show that a pole bed as constructed by the average farmer in North Carolina does not offer much protection from flea beetle infestations.

The protection afforded by the closed type bed is very apparent, and the figures presented in table 1 show that over 3 times as many beetles developed in the open and pole beds as in the closed bed. On the basis of approximately 100 square yards of plant beds devoted to the production of 1 acre of tobacco it will be seen that the open or pole types of plant bed of the average farmer growing 4 acres of tobacco can contribute from 600,000 to 690,000 beetles as compared with 180,000 contributed by the closed bed. When this is taken into consideration, in addition to the protection from injury afforded the plants growing in the beds, the value of a tightly constructed plant bed is apparent.

SUMMARY.—An experiment designed for studying the comparative value of three types of tobacco plant beds, in so far as protection from invasions of tobacco flea beetles was concerned, was conducted at Oxford, N. C., during the seasons of 1940 and 1942. In the beds of the open type the cover was pegged down to the ground on all sides; in those of the pole type there were side walls of pine poles and to these the cover was attached; and in the beds of the closed type the side walls were of well fitted boards over which the cover was drawn and fastened. The results of the experiment, as indicated by the numbers of flea beetles of the spring brood recovered from the beds, showed that more than three times as many beetles developed in the open-type and pole-type beds as developed in beds of the closed type.—2-19-43.

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POTATO TUBER MOTH QUARANTINES

Following the recommendations presented at the meeting of the National Plant Board in October 1942, that all potato tuber moth quarantines be rescinded, the quarantine officials of Montana, Oregon, and Washington, in May 1943, revoked their quarantine orders pertaining to this pest. The Commissioner of Agriculture of Idaho on May 22, 1943, revised the quarantine order (No. 11) pertaining to the tuber moth by extending the infested area to include Alabama, Georgia, Louisiana, Maryland, Mississippi, and Nebraska, as well as 7 States and the Territory of Hawaii formerly quarantined against. Under this quarantine potatoes may enter Idaho from the infested area only if inspected or fumigated for the moth.

SCIENTIFIC NOTES

Results of 1942 Experiments for Control of the Mexican Bean Beetle at Fort Collins, Colo.[1]

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It has been several years since the Colorado Agricultural Experiment Station did definite experimental work on Mexican bean beetle control. In the meantime new insecticides and improved methods of application have become available. Also, the serious shortages in our supplies of many insecticides, being caused by war priorities and increased bean growing, threaten many of our standard procedures. Tests as herein reported were begun to answer some of the many questions that arise from this situation.

Two plantings were used. Field 1 consisted of the varieties Full Measure and Pinto planted in plots of five rows 30 feet long with the plots of varieties alternating in a checkerboard fashion. The plots were planted by hand, an equal amount of seed being used for each. Twelve-foot drives were left between the pairs of blocks and a 4-foot space between the blocks of a pair. This arrangement permitted spraying the plots from the 12-foot drives and the ends of the field. The spraying was done by means of a portable spray boom with 3 nozzles directed on the row, thus simulating field spraying. The rate of delivery for the spray boom equipped with nozzles of known apertures was determined under conditions of a known pressure by means of a pressure water meter. The application rate was then determined by the time. The spraying was done with a high-pressure row-crop sprayer delivering 500 pounds of pressure to the spray boom through a 50-foot high-pressure hose. Two men carried the spray boom while a third kept time to control the rate of application. The dusts were applied with a wheelbarrow-type duster delivering two blasts of dust on each row. Each treatment was replicated 6 times, the plots being randomized. The efficiency of the different treatments was determined by comparison of the yields from the three center rows of each plot. In addition the bean beetle population was recorded 3 times during the spraying season by counting the insects on a 4-foot sample selected at random near the center of each of the three record rows of each block.

Field 2 was planted to the white navy bean Michigan Robust. The treatments were replicated 4 times on randomized plots. Here each plot consisted of six rows 40 feet long, the middle four rows of each plot being harvested for records. No population records were taken. The plots in fields 1 and 2 could not be laid out in a manner to permit a direct comparison. The first two aplications in field 2 were applied with the four-row spray boom of the crop sprayer. However, better to control the rate of application, the portable spray boom was used in making the third application.

Early in the season it was seen that the infestation was so heavy that untreated plots could not be left for comparison, so all comparisons are made with the results obtained with arsenite of zinc, since this has been our most generally used material in bean-beetle control. Approximately 125 gallons of spray per acre were applied in both fields. The dusts were applied at approximately 20 pounds per acre. Three applications of all materials were made. The first application was made June 25 and 26 when the first set of true leaves were well formed. An examination showed 1.15 beetles and 1.44 egg masses per foot of row. Injury from adult beetles was rather severe. No larvae were found. The second application was made July 9 and 10 when the plants were about 10 inches tall. The Pinto and Michigan Robust varieties were beginning to vine. The third application was made July 24 and 25. At this time a few pods on the Full Measure were about half grown. The schedule of applications was so planned that there would be no spray residue problem on snap beans.

Table 1 gives the mean plot yield, the mean larval population, and the computed acre yield for each treatment. In Field 1 the acre yields are based on rows 30 inches apart and are the total for the 2 varieties.

An analysis of variance, using the original plot yields, indidates that the experiment as a whole was highly reliable. The variation due to treatments is highly significant. The two varieties responded in a similar manner. Differences of 0.942 pounds between mean plot yields, and 23.89 between mean larval populations, are necessary for significance.

It will be noted that the rotenone spray carrying 0.015 per cent rotenone both with and without *Lethane 60*, the copper arsenate, cryolite, and the rotenone spray carrying 0.0075 per cent rotenone with *Lethane 60* are significantly better than the arsenite of zinc, while the rotenone dust and the pyrethrin dust with 0.2 per cent pyrethrins are not significantly different.

The pyrethrin dust with 0.15 per cent pyrethrin content is significantly poorer. The *Lethane 60* added to the rotenone spray of 0.015 per cent rotenone content shows no improvement in control. Unfortunately we cannot make a comparison of the rotenone spray of 0.0075 per cent rotenone content with *Lethane 60* added with a similar dilution without the *Lethane*. The plots available did not permit another treatment. However, it is interesting that this dilution with *Lethane* is not significantly different from double this strength with and without *Lethane*. The 0.5 per cent rotenone dust was not as effective as the rotenone sprays.

The reduction in the number of larvae is in most cases in line with the increased yields. This is not true, however, with zinc arsenite. The discrepancy in the case of zinc arsenite may be explained on the basis of arsenical injury. The control was reasonably efficient, but arsenical burning was quite evident. On the basis of larval populations it can be reasoned that this injury decreased the yield from 300 to 500 pounds per acre over the treatments that gave an equal control as measured by larval reduction. The two rotenone sprays of 0.015 per cent rotenone gave the greatest reduction in larvae. This reduction is significant in all cases except when compared with copper arsenate. The difference due to the addition of *Lethane 60* to the 0.015 per cent rotenone spray is not important, but the reduction of the rotenone content from 0.015 to 0.0075 per cent does show a somewhat significant loss in efficiency, although this difference is not significant when judged by yield. The rotenone dust is again found to be less efficient than the rotenone sprays. The pyrethrin dusts give the poorest control of the larvae.

[1] Scientific Journal Series paper No. 166, Colorado Agricultural Experiment Station.

Table 1.—Average plot yields, computed acre yields and larval populations in comparison of bean beetle control experiments in Field 1, Fort Collins, Colo., 1942.

TREATMENTS	MEAN PLOT YIELD, POUNDS	COMPUTED ACRE YIELD, POUNDS	MEAN LARVAL POPULATIONS[1]
Rotenone spray .015% rotenone plus *Lethane* (2.5 pounds cube, 5% rotenone, plus 10 ounces *Lethane 60*[2] to 100 gallons)	12.00	2323.2	5.0
Rotenone spray .015% rotenone (2.5 pounds cube 5% rotenone, to 100 gallons)	11.82	2287.7	9.8
Copper arsenate 3 lbs. to 100 gallons	11.70	2284.5	23.8
Cryolite (natural) 6 lbs. to 100 gallons	11.22	2190.9	53.0
Rotenone spray, .0075% rotenone plus *Lethane* (1.25 pounds cube, 5% rotenone plus 5 ounces *Lethane 60* to 100 gallons)	11.07	2142.5	36.5
Rotenone dust 0.5% rotenone	10.08	1952.1	110.7
Pyrethrin dust 0.2% pyrethrins [Pyrethrins derived from *Pyrocide* (oil extract of pyrethrum absorbed in clay and containing 2.0% pyrethrins) 1 part, carrier 9 parts]	9.32	1803.7	147.3
Zinc arsenite 2 pounds to 100 gallons	9.23	1787.6	30.2
Pyrethrin dust, 0.15% pyrethrins (*Pyrocide* 2% pyrethrins, 1 part, carrier 12.33 parts)	6.97	1348.8	169.0
Minimum difference required for significance	.942		23.89

[1] Total larval population as determined by examining all plants in 4-foot units of each harvest row of each plot July 13–14 and Aug. 13.

[2] A 50 per cent solution in a petroleum carrier of beta thiocyano ethel esters of aliphatic fatty acids with 10 to 18 carbon atoms.

The copper arsenate, a new material, gave good control as indicated by yield and larval counts. It produced a darker green color in the foliage and delayed maturity. This delay of maturity was sufficient to be objectionable under some conditions.

Table 2 gives the average plot yields and the computed acre yields for each treatment used in Field 2.

Table 2.—Average plot yield and computed acre yield in comparison of bean beetle control experiments in Field 2, Fort Collins, Colo., 1942.

TREATMENTS	AVERAGE PLOT YIELDS, POUNDS	COMPUTED ACRE YIELD, POUNDS
Phenothiazine, 4 pounds to 100 gallons	20.4	2221.6
Cryolite (synthetic) 6 pounds to 100 gallons	16.3	1775.1
Zinc arsenite, 2 pounds to 100 gallons	16.1	1753.3
Cryolite (natural) 6 pounds to 100 gallons	14.2	1549.1
Calcium arsenate 2 pounds to 100 gallons	13.6	1481.0
Magnesium arsenate 3 pounds to 100 gallons	11.8	1279.6
Minimum difference required for significance	2.60	

If we again take zinc arsenite as the standard of comparison we find that the phenothiazine gave significantly better results. The results from natural and synthetic cryolite and calcium arsenate are not significantly different from the results from the zinc arsenite, while magnesium arsenate gave significantly poorer results.

The difference between natural and synthetic cryolite is not significant.

Zinc arsenite and calcium arsenate caused noticeable arsenical injury to the foliage.

CONCLUSIONS: Phenothiazine, copper arsenate, cryolite, and rotenone sprays gave better yields than did zinc arsenite. Calcium arsenate spray, rotenone dust, and 0.2 per cent pyrethrin dust gave yields not significantly different from zinc arsenite, while magnesium arsenate spray and 0.015 per cent pyrethrum dust gave poorer results. Calcium arsenate and zinc arsenite caused noticeable arsenical injury to the plants. Natural cryolite and synthetic cryolite gave about equal results. Rotenone as a spray appears more effective than as a dust.

Copper arsenate as a spray delayed maturity of the Pinto and Full Measure varieties of beans by 4 to 6 days.

Phenothiazine and copper arsenate are materials that will probably not be generally available in 1943. The supply of rotenone-bearing materials (cube, derris, timbo) is limited on account of the war. Their use for the present should be limited to snap beans. The natural and synthetic cryolites appear, from the results of these tests, to be the most promising bean-beetle controls of the readily available materials.—6-5-43.

The Seasonal Incidence of Sand Flies in Florida

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When weather conditions in Florida become favorable for sand flies, these pests cause intense annoyance to persons visiting and residing near subtropical salt marshes. The control measures now being used consist of diking the marshes to prevent overflow of tide water and removing the rainfall within the marshes by pumping. If control can be achieved by drying the marshes just before the adult emergence, the amount of pumping, and consequently the cost, will be greatly reduced. Therefore, if peaks of sand fly abundance could be predicted with reasonable accuracy and correlated with annual variations in weather, particularly as regards rainfall, control measures could be applied to the best advantage.

To determine when sand flies emerge in greatest abundance, recovery cages were placed in four pickleweed (*Batis maritima* L.) marshes and in four red mangrove (*Rhizophora mangle* Lindl.) marshes. In each marsh a cage was placed in each of the

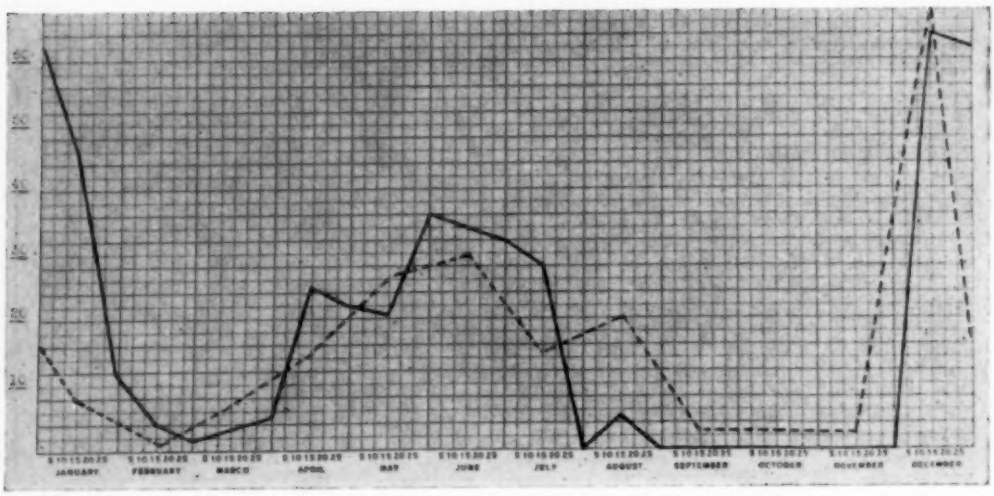

FIG. 1.—Emergence of sand flies in southern Florida.—(Solid line, 1939–40; Broken line, 1940–41.)

following locations: The drainage ditch and 5, 10, 20, 40, and 75 feet, from the ditch. In four of the marshes, two pickleweed and two mangrove, cages were installed during low tides, when the marshes were relatively dry. In the other four the cages were installed after a period of high tides. This procedure served to balance the tendency of sand fly larvae to migrate when the marshes were flooded.

These cages were like those described by Dove *et al.* (1932) except that heavier sheet metal, 12 inches in width, was used around the bottom. This strip of metal extended 10 inches into the soil and prevented any migration of larvae.

Beginning early in December there was a short and extremely heavy emergence which lasted until the middle of January and then fell rapidly. Another increase in emergence occurred early in April, dropped slightly during the next 30 days, then increased early in June, and remained fairly high through the middle of July. After a sharp drop early in August and until the middle of November, only a few sand flies emerged into the cages. (See fig. 1.)

By use of the cages described, emergence could be obtained when wind velocity, which varies greatly in southern Florida, and other weather conditions, except moisture, were reduced to a minimum. Previously the only records of emergence that the writers had were those from their own observations and from reports by residents of the infested areas. The cage records show two distinct peaks when sand flies cause the greatest annoyance if weather conditions, such as wind velocity, humidity, and temperature, are favorable. The highest peak, from late December until January 15, is short and comes when weather conditions prevent a great amount of activity by the flies. The second peak, does not reach the intensity of the winter annoyance, but occurs when the weather is favorable for sand flies to migrate to nearby residential areas.—1-4-43.

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The Wax Moth as a Household Pest[1]

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The wax moth, *Galleria mellonella* (L.), is an insect which has been well known to beekeepers since antiquity but is little known to others. A recent case of trouble caused by this pest in a residence at Exeter, Calif., seems worthy of a published note.

The life history and the control of this moth have been the subject of several publications, as for example the one by Paddock (1918) and another by Whitcomb (1942).

There is nothing exceptional about the life history of this lepidopterous insect, which has the usual four stages of development, *i.e.*, egg, larva, pupa, and adult. The moth flies at night, mostly during the evening twilight. At this time it is possible for it to gain entrance to any hive that is poorly guarded by the bees. The eggs from 200 to 300 for each female are laid on the honeycomb, and when the larvae hatch they burrow through the cell wall to the midrib of the comb. The burrows are well protected against the bees by a tough silken lining. The length of the larval period has been found to range from about 1 to 4 months, depending on temperature and other conditions.

The food of the larvae consists largely of the pollen, old bee cocoons, and other nitrogenous materials found in the combs, rather than of pure beeswax. A larva can be reared on a variety of materials not obtainable in a beehive (Haydak 1936), but the wax moth has been associated with bees so long that bee comb in some form is now practically its only food. The larvae, when their feeding period and growth are completed, usually leave the comb and pupate or hibernate in places inaccessible to the bees.

The larvae frequently drill tunnels into wood, paper, or other materials, to obtain protection during their inactive stage. The inch-thick top bars of a hive frame are often completely penetrated by their

[1] A contribution from the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, in cooperation with the University of California.

burrows, which are about ¼ inch in diameter. Before pupating the larva spins a tough white silken cocoon. When confined in tight places, the fully grown larva may drill out and then migrate a considerable distance before spinning its cocoon.

In the recent case at Exeter, Calif., a honeybee nest in the walls of a house was fumigated with calcium cyanide to get rid of the bees. Sometime after the bees were killed the housewife found that numerous "worms" were drilling through the board walls and the wallpaper of her home. They caused much annoyance and some expense. Many cocoons were found behind picture frames and other objects in the house. This is a definite instance of the wax moth becoming a household pest. Stray bee colonies are frequently found in dwellings, therefore other persons may have had similar trouble. When unwelcome bees are killed, it is best to remove the old bee combs from the walls of the house, because wax worms may be present and may readily become a more serious nuisance than the bees were.—6-30-43.

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Nornicotine in Commercial Nicotine Sulfate Solutions

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In connection with the development of a method for determining nicotine and nornicotine in tobaccos, the writers analyzed various samples of *Nicotiana tabacum* and *N. rustica* and also two commercial samples of nicotine sulfate. All these samples were found to contain nornicotine, and nearly 12 per cent of the alkaloid content of one of the nicotine sulfate samples was nornicotine.

This finding is important from an entomological viewpoint. Although the amount of work published on the toxicity of nornicotine and its compounds is small, Richardson, *et al.* (1936) and Hansberry & Norton (1940) reported that all the nornicotines (*dextro*, *laevo*, and *dl*) seem more toxic than natural nicotine to *Aphis rumicis* L. The nicotine sulfate samples analyzed by the present writers had been reported as being much more toxic to aphids on cotton than would ordinarily be expected of a 40 per cent nicotine sulfate solution.

Commercial nicotine sulfate solutions and tobacco extracts containing nornicotine may be expected to be better contact insecticides than solutions of pure nicotine sulfate. On the other hand, since nornicotine is known to be less volatile than nicotine, when a mixture of the two is used as a fumigant by burning or by spraying on a heated surface, the writers are of the opinion that the predominant effect is that of nicotine. Haag & Larson (1943) found that, when tobacco containing 0.13 per cent of nicotine and 0.27 per cent of nornicotine was burned in the form of cigarettes, the smoke contained only 4 per cent of the nornicotine present in the tobacco as compared with 29 per cent of the nicotine.

The presence of nornicotine in varying amounts in materials that have been considered pure nicotine products could easily account for erratic and non-reproducible entomological results.—7-1-43.

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Effects of Temperature and Humidity on Certain Developmental Stages of the Potato Tuber Moth[1]

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A series of experiments were performed in 1941 at University Farm, St. Paul, Minnesota to determine the effect of temperature and humidity upon the rate of development of various life stages of the potato tuber moth, *Phthorimaea operculella* Zeller. For various reasons the scheduled studies had to be terminated while still incomplete, but the results obtained are here presented.

In the experiments, temperatures of 5°, 10°, 15°, and 20° C. were maintained to within ±0.5° C. by means of insulated cabinets whose heating and refrigerating elements were controlled by mercury-toluene thermostats. Wide mouth pint Mason jars furnished with a transparent plastic substituted for the flat cover and sealed by means of petroleum jelly and the original screw cap, served as humidity chambers. Required saturation deficits in the jars were obtained by means of sulphuric acid of various concentrations (Wilson 1921). Eggs, newly deposited at "room temperature" (about 25° C.), and newly formed pupae that had developed at the same temperature, were placed in the bottom half of 1.5 dram vials maintained above the acid solutions by means of a wire screen supported by a glass tripod. Once the jars were sealed all observations could be made through the transparent plastic cover without disturbing the environmental conditions of the experiment. Some larvae were allowed to develop at room temperature until full grown and then were placed in petri dishes containing a thin layer of cellucotton. These were placed at 5° C. to see if they could pupate at that temperature.

The incubation period of potato tuber moth eggs was studied under various humidities at 10°, 15°, and 20° C. None of the 100 eggs stored at 10° C. completed their development. This series included 19, 19, 35, and 27 eggs held respectively at 2.5 mm., 5.0 mm., 7.5 mm., and 9.2 mm. saturation deficit.

The length of the incubation period at 15° and 20° C. under various saturation deficits is given in tables 1 and 2.

[1] Paper No. 2095 Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul.

[2] At present with the Maine Agricultural Experiment Station.

[3] Grateful acknowledgement is made to Dr. A. A. Granovsky, Minnesota Agricultural Experiment Station, under whose direction the studies herein reported were undertaken.

Table 1.—Length of egg stage, *Phthorimaea operculella* Zeller, at 15° C.

Number of Eggs	Saturation Deficit in mm. Mercury	Per Cent Relative Humidity	Incubation Period, Days		
			Min.	Av.	Max.
5	12.5	2.2	17.9	17.9	17.9
28	10.0	21.7	16.9	18.0	18.9
32	7.5	41.3	16.5	17.8	19.0
48	5.0	60.8	16.25	17.75	19.5
5	2.5	80.4	16.7	17.4	18.0

Table 2.—Length of egg stage, *Phthorimaea operculella* Zeller, at 20° C.

Number of Eggs	Saturation Deficit in mm. Mercury	Per Cent Relative Humidity	Incubation Period, Days		
			Min.	Av.	Max.
7	17.5	0.0	8.0	8.3	8.3
46	12.5	28.7	8.0	8.3	9.4
31	7.5	57.3	7.7	8.2	8.7
37	2.5	85.9	8.0	8.7	9.4
18	0.0	100.0	8.0	8.25	8.5

From the data obtained it would appear that, at temperatures of 15° and 20° C., humidity does not have an appreciable effect on the length of the incubation period. At 15° C. the average incubation period was 17.8 days for 118 eggs; at 20° C. it was 8.35 days for 139 eggs.

Of 266 full grown larvae developing at room temperature and placed at 5° C. only 5 were able to pupate.

At the end of 117 days when the experiment had to be terminated, only one adult had emerged from 52 newly formed pupae developing at room temperature and stored at 5° C. The remaining 51 pupae were, to all appearances, still in excellent condition. At 10° C. no adults emerged from 61 pupae stored for about seven months at the following saturation deficits: 15 at 9.2 mm., 14 at 5.0 mm., 16 at 2.5 mm., and 16 at 0.0 mm. Out of 16 pupae stored at 15° C. and 12.5 mm. saturation deficit, 4 adults emerged in 26 to 28 days.—7-12-43.

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Apparatus for Laboratory Fumigation of the California Red Scale

ROBERT A. FULTON and R. L. BUSBEY, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

For studying the toxicity of hydrocyanic acid gas to the California red scale, *Aonidiella aurantii* (Mask.), the development of a laboratory fumigation method was necessary. In regular citrus fumigation the hydrocyanic acid gas is released by means of a vaporizer inside a tent covering a tree. This produces a high initial concentration which gradually decreases until the end of the fumigation. For these studies an apparatus was desired that would duplicate decreasing concentrations of this type as well as constant or increasing concentrations. An apparatus designed by Howard (Yust *et al.* 1942) was capable of reproducing field-type concentration curves on the same day, but on account of changing atmospheric conditions the curves could not be duplicated on different days. It has since been altered to reproduce decreasing concentrations, and the new fumigation chamber and the manipulation technique are herein described.

The apparatus consists essentially of a fumigation chamber connected with a reservoir of liquid hydrocyanic acid through an ice-water-jacketed burette and a circulating duct containing a fan and a heating device for vaporizing the liquid in the burette. Two vacuum pumps are used for providing decreasing concentrations of gas in the fumigation chamber. Increasing concentrations are obtained by adding measured dosages at intervals during the fumigation.

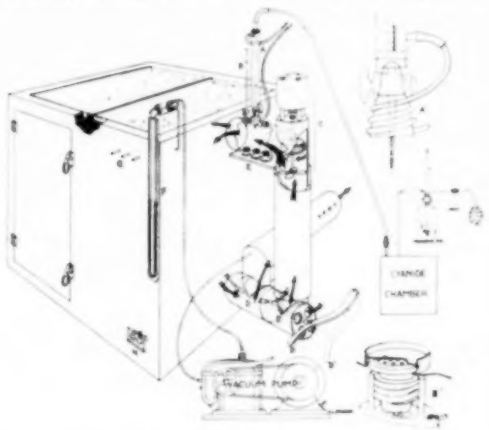

FIG. 1.—General arrangement of fumigation unit showing integral parts.

DESCRIPTION OF THE APPARATUS.—The fumigating apparatus is shown in figure 1. The fumigation chamber is constructed with sides and bottom of two layers of quarter-inch pressed fiberboard separated by 1 inch of mineral wool, and lined with copper sheeting soldered at the joints; the top is covered with two layers of glass, bedded on rubber gaskets and separated by an air space. The inside dimensions are 34 by 34 by 35 inches. On one side is a door 15 by 27 inches, provided with a rubber gasket such as is used on refrigerator doors. The temperature within the cabinet is controlled by means of a two-wire *DeKhotinsky* thermoregulator connected in series with three heating elements operated by a three-way switch so that 165, 330, or 660 watts may be used, depending on the temperature differential between the chamber and the outside atmosphere. The electrical connection for the cabinet is shown at *H*, and copper tubes for withdrawing samples of gas at *G*.

On one side of the chamber is a U-shaped duct in which is mounted a motor-operated vane-type centrifugal fan (*C*). A shutter (*D*, *D'*) is provided in the lower portion of the duct for use in exhausting the chamber. In the top arm of the duct are small ports on which are mounted burettes for introducing the liquid fumigant (*A*) or water (*B*), and directly below are small heating elements (*E*) to vaporize the liquids. The arrangement of one of the heating elements is shown in *E'*. The total volume of the duct and chamber is approximately 700 liters.

The liquid hydrocyanic acid is stored in 1-liter copper cans kept in an underground pit. It is forced

by air pressure from a rubber atomizer bulb through ¼-inch copper tubing to the 10-cubic-centimeter burette (*A*). This burette is provided with a jacket through which ice water is circulated from a tank (not shown) by a motor-driven pump, and the lower portion is cooled by means of an ice-water-jacketed cone arrangement (*A'*). Two diaphragm vacuum pumps having a capacity 2.5 cubic feet of air per minute, connected to the chamber through a flowmeter (*F*), are provided for withdrawing the air-gas mixture from the chamber.

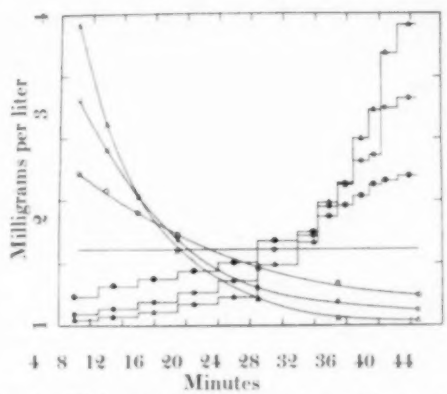

FIG. 2.—Different types of decreasing and increasing curves with an average concentration of 1.2 mg. per liter.

The fumigation chamber is installed within a large insulated room provided with a refrigerator-type room cooler, which is capable of maintaining the temperature of the room 30 Fahrenheit degrees below the outside temperature. In the room there is also a large exhaust fan for use in an emergency.

OPERATION.—A typical fumigation with a constant concentration of hydrocyanic acid is used to illustrate the manipulation of the apparatus.

The exhaust shutter is closed (position *D'*), and the circulating fan is set in operation. As soon as the temperature in the chamber has reached the desired level, the heating unit *E* is turned on. Ice water is circulated through the jacket of the burette *A* until it is thoroughly chilled, and the desired amount of hydrocyanic acid is forced into it with the aspirator bulb. Psychrometer readings are taken on the outside air, and the necessary water is introduced through burette *B* to produce the desired humidity. An amount of liquid hydrocyanic acid about equal to that to be used in the fumigation is introduced from burette *A* and circulated within the chamber for 40 minutes. This preconditioning is necessary to prevent a decrease in concentration during the fumigation because of the sorption of the gas by the walls of the chamber. At the end of this time the air-gas mixture is exhausted from the chamber by moving the shutter to position *D*. Five minutes later the shutter is closed, and the chamber is ready for the fumigation.

The test material is placed in the chamber on open trays. The hydrocyanic acid and water, if added moisture is necessary, are introduced immediately, and the exposure is continued for 40 minutes. At the end of the exposure the shutter is opened and the air withdrawn for 2 minutes. The test material is then removed.

A 2-liter sample of the gas is withdrawn from the chamber—3 minutes after the introduction of the hydrocyanic acid and again about 4 minutes before the end of the exposure. The gas is absorbed in 2 per cent sodium hydroxide solution and later titrated with standard silver nitrate in the presence of potassium iodide, a *Tyndall* light beam being used. The concentration of hydrocyanic acid is taken as the mean of the two samples. Concentrations in the range of 0.10 to 2.10 mg. per liter have been obtained with a reproducible accuracy of ± 0.02 mg. per liter.

For decreasing field-type concentrations the fumigation procedure is similar to that described above. The liquid hydrocyanic acid is first introduced, and at the end of 2 minutes the exhaust pumps are started and the flowmeter is set to withdraw the gas at a specified rate. A sample of gas is removed immediately after introduction of the test material and again at specified intervals throughout the fumigation to determine the decrease in concentration.

Increasing concentrations are obtained by adding the hydrocyanic acid at specified intervals throughout the fumigation. A sample of the gas is withdrawn for testing immediately after each addition. This method of producing increasing-type curves is essentially a series of definite increments to produce the desired average concentration.

A series of increasing and a series of decreasing curves with an average concentration of 1.2 mg. per liter are shown in figure 2. A line showing a constant concentration of 1.2 mg. per liter is used to illustrate the change necessary to produce the same average concentration ($\Sigma C\Delta t/t$). These curves have been reproduced on different days with the same accuracy as was obtained with the constant concentration.—6-23-43.

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The Corn Earworm Infestation of 1942

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Heavy general infestations of the corn earworm in Maryland occur as a result of two or more consecutive years favorable to its hibernation. Thus the seasonal population level became higher from 1937 to 1939; was greatly reduced by the severe winter of 1939–40; then increased again in 1941 and 1942. High winter soil temperatures appear to be the most important but not the only factor favorable to a high carry-over of earworm pupae in the soil. The prolonged warm fall of 1940, which greatly extended the pre-hibernation period, was followed by a mild winter; as a consequence the earworm population was high the summer of 1941. The winter of 1941–42 was again mild followed by a dry spring, which also favored high pupal survival and provided a second consecutive extremely favorable hibernating season with the result that the 1942 earworm infestation was severe.

Examination in 1942 of early season tomatoes on the Eastern Shore showed one to four fruit per plant infested, while green wrap tomatoes arrived at packing houses with as high as 20 per cent of the fruit damaged. Heavy injury was suffered by sweet corn, and in late summer and early fall, after the corn

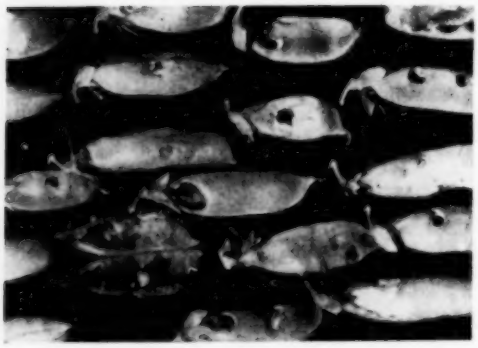

FIG. 1.—Injury to peas by the corn earworm.

season, severe losses were caused to snap and lima beans. Two acres of fall peas at Ridgely, Maryland were so completely injured (Fig. 1) that hardly a single pod escaped. In this infestation the heaviest parasitism of earworm ever observed by the author occurred. One or more tachinid eggs of an undetermined species were noted on each larva observed in late September and early October (Fig. 2).

Insecticidal control experiments were carried out on snap and lima beans in the late summer and fall of 1942. Rotenone-bearing dusts at 30 to 60 pounds per acre were ineffective; calcium arsenate dusts at 30 to 63 pounds per acre not only were ineffective but also caused the following injury to the bean plant: bunch lima bean plants were eventually defoliated and yields greatly reduced; on snap beans defoliation was not so severe, but the fruit was discolored with small black spots surrounded by green margins.

FIG. 2.—Earworm larvae parasitized by a tachinid parasite

Cryolite dust (80 per cent cryolite, 20 per cent sulphur) at 15 to 50 pounds per acre gave sufficient control of the larvae on both lima and snap beans to warrant its use. On lima beans, infested pods were reduced from 29 to 9 per cent, and on snap beans from 21 to 2 per cent. This cryolite mixture at 11 pounds per acre failed to control the earworm, the optimum practical amount appearing to be 20 pounds per acre. Since cryolite dust does not control bean beetle, suitable treatments must be made for this insect.—5-5-43.

Belladonna Insects in Pennsylvania[1]

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Because it is no longer available from Europe, the Solanaceous plant belladonna, *Atropa belladonna* L., which yields the drugs belladonna and atropine, is now being grown in this country, about two hundred acres being cultivated in Pennsylvania in 1942. Most of this was produced in Lancaster, Chester and Delaware counties, in southeastern Pennsylvania. In Lancaster county most of the crop was grown by tobacco growers, since it is raised in a manner very similar to that used for tobacco. The seedlings are first grown in greenhouses or cold frames, then set in the field at about two foot intervals, the rows three to four feet apart. The plant grows to about 2.5 to 3 feet tall, and the top leaf stalks are removed before the stalks are more than a half-inch in diameter, but generally after the bell-shaped flowers appear. Three or more cuttings are made per season from each plant, and the crop is produced over a two year period. During the late fall the plants are cut back, and either the roots are removed to storage or the rows are mulched with straw or by cultivating soil over them.

The leafy stalks removed are hung upside down to dry in a room in which there is a forced draft of warm air. This dries the leaves and stalks rapidly, and helps to prevent mold growth. In some localities special drying machines are used. The dried plants are pressed into bales for shipping.

Since belladonna is a member of the family *Solanaceae* and closely related to tobacco, potato, tomato, and the weeds horse nettle and ground cherry, it is subject to many of the same insects which affect those plants. In a preliminary survey during 1942, the writer found that belladonna was attacked by many of our important pests such as European corn borer, corn ear worm, Japanese beetle, flea beetles, and numerous others. The following list shows those species which have been positively identified as feeding on belladonna in this state. A few more species, not yet identified, will be published in a later list. The writer wishes to express his appreciation to Dr. S. W. Frost, Pennsylvania State College, for identifying numerous specimens in the orders Lepidoptera and Diptera. To Mr. Lawrence Wolcott of Kennett Square, and to many growers thanks are also due for numerous specimens from their belladonna fields.

MOLLUSCA:

Limax, species not determined. These small brown slugs caused some injury by eating the leaves of small plants, especially in pots and in the seedbeds. Some feeding also occurred on field plants.

ARTHROPODA

CLASS ARACHNIDA:

Order Araneae:

Philidippus audax Htz.—This small spider made webs among the new growth, so that it sometimes did not develop properly. Determined by S. W. Frost.

Order Acarina.

Tetranychus telarius L.—Red spider mite, found occasionally on small plants in the greenhouse.

[1] Authorized for publication on January 22, 1943, as Paper No. 1159 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

CLASS INSECTA
Order Homoptera.

Family Cicadellidae:

Empoasca fabae (Harr.)—Potato leaf hopper, found occasionally on belladonna plants. Injury not extensive.

Family Aphididae:

Macrosiphum gei (Koch).—Potato aphid. This species is sometimes quite common, especially on seedlings, curling and yellowing the leaves.

Myzus persicae (Sulz.)—Occasional on small plants.

Family Aleyrodidae:

Trialeurodes vaporariorum (Westw.)—Greenhouse white fly. Fed on seedlings in the greenhouse; scattered adults seen on field plants.

Family Coccidae:

Pseudococcus citri (Risso).—Citrus mealybug. Fed on greenhouse seedlings.

Order Hemiptera:
Family Neididae:

Jalysus spinosus (Say)—Tomato stilt bug. Occasional on new growth. Injury not observed.

Family Miridae:

Adelphocoris rapidus (Say)—Rapid plant bug. Scattered, not common. Feeds on buds and young leaves, deforming them.

Poecilocapsus lineatus (F.)—Four-lined plant bug. Occasional especially seen in early summer. Feeds on the new central leaves of young plants, causing distortion and many small sunken, discolored spots. These leaves become dark and die.

Lygus pratensis (Say)—Tarnished plant bug. This insect is sometimes quite common on belladonna, where it appears to do some injury to the buds.

Order Coleoptera:
Family Scarabaeidae:

Popillia japonica Newm.—Japanese beetle. The larvae occasionally cut the large roots where planted in former sod lands. In a field in Lancaster county, adult beetles caused some injury by feeding on the upper leaves of several plants, especially along the edge of the field near smartweed plants.

Family Chrysomelidae:

Lema trilineata (Oliv.)—Three-lined potato beetle. The small larvae of this beetle are sometimes quite common, feeding in groups along the leaf wounds; they have the peculiar dirty habit of piling their feces on their backs.

Leptinotarsa decemlineata (Say)—Colorado potato beetle. Has been found occasionally feed-on the upper leaves.

Diabrotica duodecimpunctata (Fab.)—Spotted cucumber beetle. The adult beetles are sometimes quite common, though scattered, feeding on the younger leaves. The larvae have also been found on the roots.

Epitrix cucumeris (Harr.)—Potato flea beetle. This and the next species are among the most injurious insect pests of belladonna in Pennsylvania. They first attack the seedlings, perforating the leaves, and injure field plants throughout the year. They are especially common where horse nettle, *Solanum carolinense* L., occurs in the field.

Epitrix parvula (F).—Tobacco flea beetle. This tiny beetle is also common and injurious to belladonna leaves, especially in the Lancaster county tobacco district.

Family Curculionidae:

Trichobaris trinotata (Say)—Potato stalk borer Although this has so far been only a minor pest in southeastern Pennsylvania, Dr. A. F. Sievers, U. S. Bureau of Plant Industry, reports that it caused serious damage to late planted belladonna in the vicinity of Appomattox, Virginia, and in Tennessee, in 1942. It was not serious in fields planted before June 1.

Order Lepidoptera:
Family Sphingidae:

Protoparce quinquemaculata (Haw.)—Tomato hornworm. During September and October this larva became common, and caused considerable damage to belladonna.

P. sexta (Johan.)—Tobacco hornworm. This was even more common than the tomato hornworm as a belladonna pest this past fall. These larvae ate large holes in the leaves, frequently stripping them to the large ribs. Many were carried into the drying rooms with the crop and dropped to the floor. Parasitism was low among these larvae.

Family Arctiidae:

Isia isabella (A. & S.)—Banded wooly bear. This larva is quite common on belladonna in July to September, eating irregular holes, especially in the new growth.

Family Noctuidae:
Subfamily Agrotinae:

Heliothis armigera (Hbn.)—Corn earworm. This was one of the most common and most injurious belladonna pests in the late summer and fall. The larvae ate large holes in the new leaves, and bit shallow holes into the stems. Large numbers of them dropped from the drying plants to the floor of the drying rooms.

Porosagrotis vetusta Wlk.—Spotted-leg cutworm (Det. Frost). Occasionally found with other cutworms eating ragged holes into the leaf edges at night.

Subfamily Acronyctinae:

Laphygma frugiperda (A. & S.)—Fall Army worm (Det. Frost). One occurrence in considerable numbers in Delaware county. Several scattered individuals in Chester and Lancaster counties.

Papaipema nebris (Guen.)—Common stalk borer. Occasionally found boring in belladonna stalks.

Family Pyralidae:
Subfamily Pyraustinae:

Phlyctaenia rubigalis (Guen.)—Greenhouse leaf tier. This slender greenish larva webbed the central leaves of the large belladonna plants. In some fields it was common and quite injurious.

Pyrausta nubilalis (Hbn.)—European corn borer. Found boring into belladonna stems in two fields; in one field near Kennett Square this injury was quite extensive. The part of

the plant above the bored stem wilted and died, a total loss for the grower.

Family Gelechiidae:

Keiferia species, probably *K. glochinella* Zeller, according to A. Busck. This larva was occasionally found making blotch-type mines in the leaves in one field near Moylan, Delaware county, in September, 1942.

Family Tortricidae:
Subfamily Tortricinae:

Sparganothis (*Platynota*), probably *rostrana* (Wlk.) Det. Frost. An introduced species, attacking pepper and tomato. On belladonna it webs and feeds on the central new leaves. Not common.

Argyrotaenia velutinana (Wlk.)—Red-banded leaf roller. Det. Frost. This larva was quite common rolling and webbing the new leaves in a few fields in June through August. Large holes were eaten in these leaves.

Order Diptera:
Family Anthomyiidae:

Pegomyia hyoscyami (Panz.)—Spinach leaf miner. Det. Frost. This miner has been found occasionally in seedlings in seed beds in Lancaster county, but is not common. It makes an irregular blotch-type mine, as in spinach. Screening the seed beds is helpful.—2-17-43.

Density and Particle Size of Derris and Cube Powders

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The insecticidal powders the particle fineness of which has been studied by means of the self-calculating air-permeation apparatus (Gooden & Smith 1940; Gooden 1941a and b, 1942) include ground derris and cube roots. The permeation method requires a knowledge of the density of the material composing the powder particles. The densities of many insecticidal powders are well known or easily determined, but with porous materials, such as powdered woods, the density varies with the state of subdivision. The density of a wood as ordinarily stated is the minimum density, because all the pores in a timber or block are included as part of the geometrical solid. If the wood is pulverized so finely as to be separated into its ultimate constituents (fibers, starch grains, etc.), then the pores are eliminated and the density has its maximum value. In sawdust or coarse powder, where only part of the pores are eliminated, the density has an intermediate value depending on the fineness of subdivision, and its determination often defies accurate solution. For that reason there has been used in this Bureau a tentative density value for derris and cube, known to be of the same order as the true value, but admitted to be only a rough estimate. This value is 1.00 gram per cubic centimeter, which is near the densities of various whole dried derris roots, and has been used uniformly for tests of powdered derris and cube.

This procedure has proved adequate for comparing derris and cube samples among themselves, but more and more pressing has become the need for comparing them with other materials of quite different nature. Experimental study was required to arrive at a more accurate estimate of the densities of derris and cube in the form ordinarily appearing on the market.

Various methods have been used for determining densities of porous materials. Darkis, *et al.* (1942), in studying the influence of several variables in determination of tobacco density with a Hubbard pycnometer, found variations of about 3 per cent between 20-mesh and 100-mesh grinds, and somewhat greater differences in changing from water to certain nonsolvent organic liquids for the filling media. Washburn & Bunting (1922) showed that, with a liquid filler (*e.g.*, mercury) that does not wet the sample material, the pressure can be adjusted to make the liquid permeate pores down to a preselected size. Ideally, one can thus determine the density of porous materials in powder form by having the liquid fill the interstices between particles but not the pores within the particles. The authors point out, however, that the method is valid only for samples that are fairly homogeneous in particle size. This and other drawbacks render the method impractical for use with derris and cube powder.

Approximate densities, in grams per cubic centimeter, of several known constituents of derris root are: Cellulose 1.59, starch 1.50, resin 1.30, and rotenone 1.33. The volume-weighted average of the densities of all the chemical constituents is probably about 1.50. The density of the powdered root can not be quite so great as this average, but microscopic examination of representative commercial samples as to the degree of subdivision suggests a rather close approach to the properties of the ultimate chemical constituents. In other words, the density may be expected to lie between 1.00 (approximate for unground root) and 1.50 (approximate for chemical constituents), but much nearer the latter figure. The method of determination, therefore, should be very similar to that employed for chemical sustances, with some modification to allow for the porosity existing in some of the particles. Since the adjusted-pressure method mentioned above is inapplicable, the best substitute that presents itself is to use a pycnometer with a liquid that wets the sample readily, and take the reading as soon as possible after introduction of the liquid, in order to approach the ideal condition of permeation of interstices between particles without internal soaking of those particles that are porous.

Determinations based on this principle were made on several samples of derris and cube, with three filler liquids—water, toluene, and high-boiling refined kerosene. Water was found unsatisfactory in manipulation, at least with derris. Toluene gave slightly higher results, on an average, than kerosene, perhaps owing to greater solvent action. Kerosene gave the lowest density values, on an average, of the three liquids. With kerosene the six samples studied (three each of derris and cube) gave densities ranging from 1.34 to 1.45 grams per cubic centimeter, with an average between 1.40 and 1.41, and the separate averages for the two plants did not differ significantly between themselves. On the basis of these experiments it is concluded that 1.40 grams per cubic centimeter is a practical estimate of representative density for both derris and cube in commercial powdered form.

Something may well be said here as to the effect of this revision of the density estimate on the values derived for average particle diameter (surface mean diameter). The error in mean diameter is relatively greater than the density error that causes it. Calculations based on formulas in the original description of the apparatus (Gooden & Smith 1940) show that

the percentage error in mean diameter caused by the use of a given erroneous density estimate will vary with the degree of compaction of the powder. Both theory and observation have shown that, in the range of porosities commonly obtained with commercial derris and cube powders, the average-diameter value resulting from the use of the new density estimate (1.40 grams per cubic centimeter) will be around 0.4 times the value obtained on the former density basis. A sample rated on the old basis as having a surface mean diameter of 15 microns (common for derris) on the new and more accurate basis will be rated as having a value of approximately 6 microns.

Thus it is seen that, despite the presence of coarse fibers, the common derris and cube powders are rather fine as to average particle diameter, and appreciably finer than heretofore rated.—3-1-43.

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Age Variations in Exoskeletal Composition of the Sugar Beet Webworm and Their Possible Effect on Membrane Permeability[1]

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In testing the contact action of various pyrethrum dusts and sprays on the larvae of the sugar beet webworm, *Loxostege sticticalis* L., the authors found that this material was highly effective against the first and second larval instars, less so against the third, of little effect against the fourth, and practically ineffective against fifth. They found the same thing also to hold true when the action of a series of oil sprays was tested.

A great deal has been written concerning the effects on insects produced by the action of both of the above materials. The specific action of pyrethrum is a well established fact but the reasons for such specificity have not, as yet, been explained.

To account for both the entrance and the toxicity of oils, many theories have been advanced, a number of which take into account only a morphological difference in explaining specific action. It is doubtful that the reason for such action in either pyrethrum or oil sprays lies wholly in physiological or morphological changes within the insect as its development proceeds or to similar differences between species. More probably the reason lies in functional differences in the exoskeleton, through which structure the insecticide must pass before exerting its toxic effect.

In the past minor significance has been attached to the role of the membrane in insect toxicology, but the authors believe that without more detailed knowledge concerning the composition, structure, and physico-chemical behavior of the membranes, the fundamentals of insect toxicology cannot extend beyond the speculative stage.

The analysis reported herein is not offered as a complete explanation of the specific behavior of the membrane, but rather to point out differences in it composition which may help to explain the observed differences in the behavior of the sugar beet webworm toward pyrethrum and oil sprays.

In order to obtain the exoskeletons free from any other materials, live larvae were first dipped into boiling water to coagulate the proteins and then pinned in a dissecting tray under water, opened longitudinally and all of the cellular structures removed. The thin transparent exoskeleton was then washed several times with distilled water in order to remove any blood or other body fluids which may have adhered to it. In this manner sufficient material was obtained from third, fourth, and fifth instar larvae to carry out the determinations. Owing to the difficulties encountered in obtaining a sufficient quantity of membranes to carry out the determinations, the first and second instar larvae had to be eliminated from the study.

The exoskeletons were first dried to constant weight *in vacuo* over sulphuric acid at 40° C. From these the crude fats were then extracted in a soxhlet extractor with diethyl ether, the remaining material then being dried and weighed. This material was then treated with 18 per cent potassium hydroxide at 60° C. until hydrolysis of the proteins was completed, after which time the remaining solid material was filtered off, washed several times with distilled water followed by alcohol and ether, after which it was dried to constant weight, the loss in weight being recorded as crude protein. The remaining material was then ashed at 450° C. for 16 hours and the loss in weight in ashing recorded as chitin. The results are given in table 1.

Table 1.—Percentages of ether extractable fat, crude protein, chitin and ash in the dry exoskeleton of the third, fourth, and fifth instar sugar beet webworms.

INSTAR	FAT	PROTEIN	CHITIN	ASH	UNACCOUNTED FOR
3	11.7	82.9	1.4	0.23	3.7
4	3.9	91.3	1.6	0.28	2.9
5	0.2	93.7	2.3	0.31	3.5

The data show that a decided decrease in the percentage fat content of the exoskeleton accompanies development of this insect. At the same time an increase in the percentage of protein, and to a lesser extent chitin and ash, are noted.

[1] Contribution from Montana State College, Agr. Exp. Sta. Journal Series No. 180.

The solution hypothesis on permeability postulates that those substances which are fat soluble will readily traverse a membrane in which fatty materials form the continuous phase while those substances which are water soluble will only penetrate a membrane readily in which water is the continuous phase. In either case the materials are presumed to enter entirely by solution methods. It is not easy to picture a membrane which would comply in its entirety with the above conditions as we know that such things as electric charge, orientation of surface molecules, surface forces, etc. would all exert their effects on such a transfer. It is recognized that a membrane containing a relatively high percentage of fat does not necessarily have an even distribution of this material throughout it, or that such a membrane would form an absolute barrier to insecticides in aqueous solution. It is possible, nevertheless, that a membrane containing practically no fatty materials would present a much greater barrier to oil soluble substances than one containing a considerable amount of fat. If this is true one would expect the third instar larval exoskeletons to be more permeable to both pyrethrum and oils than those of either the fourth or fifth instar larvae, the latter having the chracteristics of a membrane which would be much less permeable to such substances.—5-31-43.

The Confused Flour Beetle Living in Bait Mixtures Containing Cryolite[1]

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In 1940 synthetic cryolite (85 per cent sodium fluoaluminate) was mixed with corn meal at the rate of 1 pound to 25 pounds as a poison bait. Part was used and the remainder was set aside in a paper bag. Two and a half years later many flour beetles were found in the mixture and a study was made of the infestation.

Nine samples were taken at approximately equal spaces from top to botton, the whole standing a foot deep in the bag. All levels were rather uniformly infested, 91 ± 12 beetles per 100 grams. A 21 gram sample taken about 5 inches from the top contained 345 larvae and larval skins; another from the bottom about 250. From the rest of the mixture, about 21 pounds, there was removed with a 16 mesh screen 27.5 cc. of beetles and 6.5 cc. of larger larvae. Eighty per cent of the beetles and all the larvae were alive. All of one hundred beetles examined were *Tribolium confusum* Duv.

These counts are given to show the extent to which the beetles were breeding in the mixture which contained 3.3 per cent cryolite. The source of the infestation is unknown, possibly larvae were in the original meal, or beetles may have entered after the mixture was made. An examination of the cryolite from the same bag from which the mixture was made showed much variation in particle size, from 39 microns down to about 1.5, but most particles were less than 4 microns. The meal was relatively coarse, the bulk being in particles 0.25 to 1 mm., though there were pieces of bran as wide as 3 mm., and much finer material, 20 to 40 microns. Judging from the pink color of the cryolite, it appeared to be uniformly mixed through the meal, but the larger particles were not well covered.

Only one report relating to the effect of cryolite on the confused flour beetle is known. Dobroscky (1935) compared the toxicity of natural cryolite and lead arsenate mixed with flour at various concentrations on beetles of this species. At 20 per cent, the weakest strength of the insecticides used, 60 per cent of the beetles in cryolite died in 8 days, as against 10 per cent mortality for the lead arsenate mixture.

Attia (1930) (as reported in Rev. Appl. Ent. Ser. A. 19: 472) mixed sodium fluosilicate with wheat, 1 to 3000, and completely controlled *Sitophilus oryza* in a 2 to 3 weeks, "but *Tribolium confusum* proved to be more resistant."

Dr. R. T. Cotton informs the author that flour beetles are troublesome pests of poison bran baits containing arsenicals.

TOXICITY TESTS.—Following up these observations, tests were made with flour beetles in various mixtures of cryolite under controlled conditions. Mixtures of synthetic cryolite ("*Magnetic cryolite*—not less than 85 per cent sodium fluoaluminate") and natural cryolite ("*Kryocide*—not less than 90 per cent sodium fluoaluminate") were made with fresh corn meal and wheat flour at three strengths: 1 part insecticide plus 25 parts carrier, 1 plus 9, and 1 plus 4. The meal mixtures were sifted twice through a 16 mesh screen, the flour mixtures twice through a 50 mesh screen. The original mixture was used also, after sifting through a 16 mesh screen.

The insects for the tests were taken from the original bag of corn meal and cryolite and held in two jars, beetles and larvae separately, for eight days before use. On the day of setting up the experiment the insects were allowed to crawl up on cards and then counted off into containers.

Two sizes of cages were used, 95×23 mm. shell vials and half-pint jars. Into each vial was put one teaspoonful of mixture (about 4 gms.) and into each jar one or two tablespoonfuls. Ten insects were put into each vial on top of the mixture and 50 to 150 into each jar. Four vials of beetles and four vials of larvae were used with each of the 15 materials, and in addition a jar each of beetles and larvae were used with 8 of the materials. From December 5 to 18 they were kept in a room with temperatures fluctuating from 37° to 59° by night to 70° or 75° by day; after December 18 they were kept in a room heated uniformly at 80° to 85° F.

RESULTS AND DISCUSSION.—Counts of live and dead insects were made by sifting them from the mixtures at intervals of 7 to 22 days, the last February 8. The results are shown for each material in figure 1.

The 1 to 25 meal mixtures gave low kills with either synthetic or natural cryolite, although more beetles died in the original mixture than in four others. It is not exact to call this the "original" because the larger particles (over 1 or 1.5 mm.) had been sifted out. Even at 1 to 9 and 1 to 4 parts of meal many insects survived.

Flour mixtures gave decidedly higher and quicker kills than those with meal. In the beetle cages all flour mixtures (6) gave complete kill in 48 days; with the larvae five cages gave 100 per cent and one gave 96 per cent kill in 65 days.

The natural cryolite was somewhat less toxic than the synthetic—seven lots with natural cryolite did not reach complete mortality and averaged 68 per

[1] Paper No. 113, Journal series, Georgia Experiment Station.

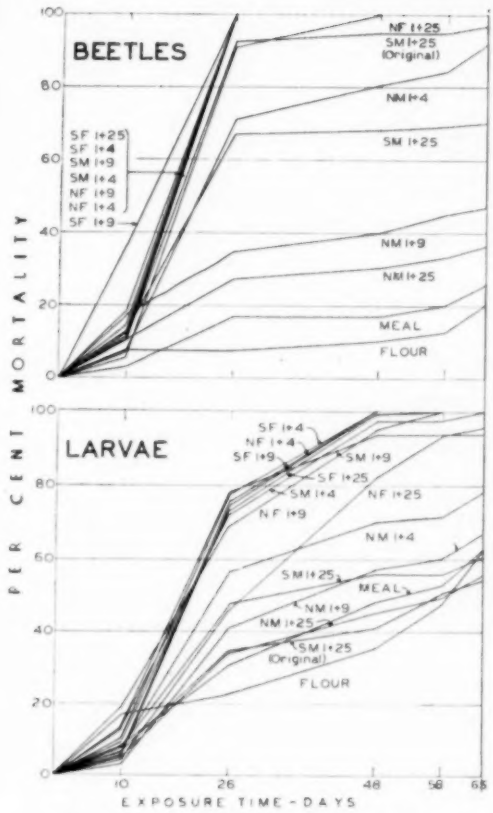

FIG. 1.—Mortality of beetles and larvae fed cryolite baits.

cent; five lots with synthetic cryolite were below 100 and averaged 75.5 per cent mortality.

In most of the poison mixtures beetles died quicker than larvae, there being seve nmaterials in which all beetles died by the second examination, whereas there were only six in which all larvae died, and in none of these were all dead before the third examination. However, in the checks more larvae than adults died, further emphasizing the resistance of the larvae to the insecticides.

Cotton *et al.* (1942) have shown that the development of insects in stored wheat is greatly influenced by moisture content. Summing their results with wheat treated in nine ways and held from 86 to 112 days (their table 4, omitting the borax treatment but including the check) confused flour beetles in presence of 10 per cent moisture increased to 5 times the original number, those in 12 per cent to 3.7 times, and those in 16 per cent moisture to 12.5 times the original.

To check the possible effect of moisture in the present study the water content of part of the samples was determined January 22 near the end of the experiment (Table 1). Flour mixtures averaged 0.7 per cent more water than the meal and with cryolite the moisture was reduced.

Perhaps the additional water in the flour mixtures was enough to bring about greater insect activity and cause higher mortality in these lots as compared

Table 1.—Per cent water in various mixtures.[1]

Flour	11.3	Meal	10.6
S F 1+25	10.9	S M 1+25	10.5
N F 1+25	10.6	N M 1+25	10.0
S F 1+ 4	9.6	N M 1+ 4	8.5
Average	10.6	Average	9.9

[1] Determinations made by Dr. Mary Speirs, Home Economics Department. The symbols are the same as used in figure 1.

with the meal. However, mortality was slightly lower in untreated flour than in untreated meal.

Not only did insects remain alive in the presence of cryolite but development and reproduction took place. All the poison cages starting with larvae had at the end of 65 days 22 adult beetles and 97 pupae. Over 1,200 cast skins were removed from these cages, which was about one for each larva put in. The check cages produced 4 adults, 17 pupae, and 101 skins from 80 original larvae.

In the beetle cages, five poison series in which beetles lived to the end, had 1809 larvae of varying sizes or 3.8 for each beetle originally caged. The check cages had 399 larvae, 5 per original beetle. It is possible that some of these were in the materials at the start, although a thorough examination on February 10 of the flour, meal, and original meal-cryolite mixture from which all cages were stocked revealed no live larvae.

In conclusion, these observations and studies show that the confused flour beetle thrives in mixtures of corn meal and cryolite at proportions of 25 to 1 and stronger and that the species can live several weeks in mixtures of wheat flour and cryolite.—3-1-43.

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Damage to Tobacco by a Local Outbreak of *Heliothis armigera* and Some Control Methods Employed

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Although the corn earworm, *Heliothis armigera* (Hbn.), is recorded as a pest of tobacco, it normally causes much less damage than do hornworms, budworms, or flea beetles. Between May 25 and June 4, 1942, however, an outbreak of this insect occurred on two farms in South Carolina where the damage to tobacco assumed major proportions and the growers sought assistance in control.

The corn earworm larvae on these farms had bred

on hairy vetch that was growing near the tobacco. The vetch had produced seed pods, but the larvae destroyed most of them before they left the vetch. On one farm the grower had 14 acres of tobacco that was 20 to 24 inches high at the time of attack. The rows ran lengthwise to a 6-acre field of vetch, and the larvae had moved from the vetch into the tobacco. On the other farm the grower had a 3-acre field of vetch adjacent to a public highway. The earworm larvae had left the vetch, crossed the highway, and attacked tobacco that had 6 to 8 leaves per plant at that time. The same grower had 12 acres of mixed vetch and oats on another part of his farm. Earworm larvae developed in this field and moved in all directions to attack tobacco, sweetpotatoes, soybeans, corn, cotton, velvetbeans, wheat, and, to a less extent, sugarcane.

Although the tobacco differed in age, typical earworm injury was present on both farms. Where small plants having 6 to 8 leaves per plant were attacked, the bud of the plant was destroyed by the boring of

FIG. 1.—A tobacco plant nearly half grown showing a corn earworm larva feeding in the bud.

the larvae, and even though as many as 15 larvae infected a plant there was very little injury to the leaves. It was necessary to top (cut back) these plants near the soil surface so that a sucker plant could be produced. In the field of half-grown plants the larvae not only destroyed the bud (Fig. 1), but ate the leaves and bored into the stalks. The stalk-boring habit of the larvae was characteristic, and caused more damage than the leaf injury. Frequently several larval burrows occurred in one stalk, and each plant had to be cut below the lowest burrow to prevent it from later falling to the ground.

An estimate of the damage to the two infested tobacco fields was made on June 9. In the 2-acre field where small plants were attacked, it was found that in 66 per cent of the plants the bud had been destroyed. In the 14-acre field where half-grown plants were attacked, a count of the first 15 rows (6168 plants) showed that 11.5 per cent of them had to be cut near the soil surface and an additional 17.4 per cent had to be topped. In the row nearest the vetch 99.3 per cent of the 447 plants had to be cut near the ground for a sucker crop.

An estimate of the loss sustained by the two tobacco growers was obtained from them after the tobacco had been harvested and comparisons could be made with uninjured fields. On the farm where half-grown plants had been attacked, the grower estimated that he lost $400 as a result of injury to tobacco and sweetpotatoes. On the farm where small plants were attacked, the grower estimated that he lost $700 as a result of injury to tobacco.

To control the infestation on the tobacco it was essential to eliminate the source of the infestation. In an effort to do this, the vetch was dusted with undiluted cryolite, but rains interfered with the work, and cultural control became necessary. The infested vetch on both farms was cut up thoroughly with a disk harrow and plowed under cleanly. The fields were then disked again to leave the soil surface rough and thus reduce the movement of the few larvae that survived the first disking and plowing. In addition, a deep furrow was plowed around the vetch fields in such a way that it was turned toward the vetch, leaving the bar or steep side of the furrow next to the field to be protected. Holes about 6 inches deep were made with post-hole diggers every 12 to 14 feet in the bottom of the furrow, and large numbers of the larvae were trapped in these holes where they died without further treatment. The use of post holes was suggested by O. O. Dukes, the county agricultural agent, and was of considerable value, but this method must be applied before the larvae begin to leave the vetch field in numbers. These cultural control methods destroyed a high percentage of the larvae, and it is believed that they not only aided in the control of the larvae on tobacco, but prevented the development of a subsequent brood that might have caused damage to tobacco or to some other crop.

Only a small amount of experimental work was possible in the 10-day period when the earworms were causing the most damage. When examination of the infested fields showed that the boring activity of the larvae was more important than the leaf feeding, baits were tried more extensively than any other form of control, although both dusts and sprays were also tested. The most satisfactory control was obtained with a bait prepared by mixing 2 pounds of barium fluosilicate or 4 pounds of cryolite with 48 pounds of corn meal or wheat middlings. This was applied directly to the tobacco plants at the rate of about 48 pounds per acre for large plants. A bait composed of 1 pound of lead arsenate and 75 pounds of corn meal, ordinarily used in combating the tobacco budworm, *Heliothis virescens* (F.), failed to give control, even when excessive quantities were applied. When the proportion of lead arsenate in the bait was increased, the bait injured the tobacco.—4-25-43.

A Comparison of Codling Moth Captures by Bait Trap and Rotary Net

C. C. ALEXANDER and F. W. CARLSON, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In order to study the normal flight habits of the codling moth when it is not attracted by lights or baits, an electrically operated rotary net was used. In construction it was similar to those made by Chamberlin and Lawson (1940) and others. Two nets were rotated in a horizontal plane at 10 and 15 feet above the ground, respectively, and were set to

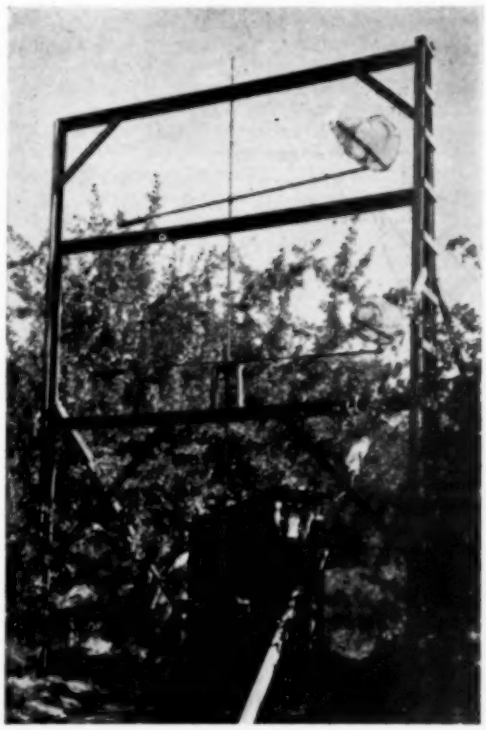

FIG. 1.—Rotary net used in making codling moth population studies, Yakima, Wash.

swing as near to two apple trees as was possible without striking them (Fig. 1). The speed of the nets was about 20 m.p.h. The cone-shaped nets, 18 inches in diameter at the large end and 3 inches at the small end, were constructed of screen wire. Detachable cloth bags were placed on the small ends to retain the insects. An automatic switch started the nets at about 6 o'clock each evening, and operation continued all night until the moths were removed at about 8 o'clock in the morning. The cloth bags containing the insects were placed in a killing jar before the moths were counted.

For comparison, two bait traps were placed in trees respectively 150 feet north and 225 feet south of the net and about 15 feet from the ground. Each trap consisted of a 2-quart, enameled stew pan containing a fermented bait made of 1 part of beet molasses and 9 parts of water.

The total numbers of moths caught in the lower net as compared with those entering the bait traps during 3 seasons of operation are shown in table 1.

Table 1.—Codling moths caught in lower rotary net and in bait traps.

YEAR	RECORD PERIOD	NUMBER OF CODLING MOTHS CAPTURED	
		Lower Net	*Per Bait Trap*
1940	June 25–Sept. 1	4,391	5,254
1941	April 18–Sept. 15	5,471	5,896
1942	May 5–Aug. 5	2,616	2,566

The upper net caught only 10 per cent as many moths as the lower net, and its use was discontinued early in 1941.

In the early part of the 1940 season the number of moths caught in the net agreed well with the number caught in the bait traps, but it dropped off more rapidly after the middle of August. The cumulative numbers of moths caught in the net and bait traps in 1941 and 1942 are shown in figure 2. Until about the first of August each year the number caught in the net was greater than the average number caught in the bait traps. After this date, especially in 1941, the catch in the net dropped off more rapidly than that in the baits.

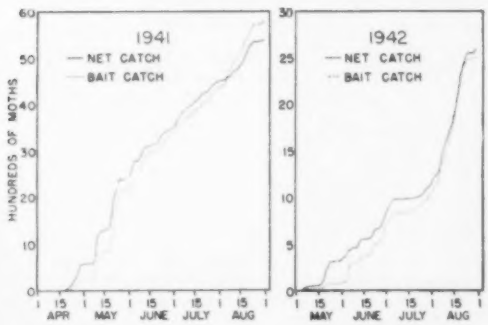

FIG. 2.—Cumulative numbers of moths caught in the rotary net and the average catch of two molasses bait traps in 1941 and 1942, Yakima, Wash.

In 1941 and 1942 about 90 per cent of the moths caught in the net and 65 per cent of those caught in the baits were males, and these percentages were quite consistent throughout both seasons. Early in June 1941, two additional bait traps were placed in trees several hundred feet from the net and from the other traps. These were suspended on poles so that they were just touching the branches at the periphery of the tree and were only about 10 feet above the ground. This location in relation to the tree was similar to that sampled by the net. These traps caught little more than half the number of moths caught in the net or in the traps that were placed in the tops of trees. Only 56 per cent of the moths caught in these lower traps were males.

Dyed moths were released on two occasions, in July and August 1942, about 165 feet from the net and traps. Of 350 moths released, 23 were caught in the net and 46 in the 2 bait traps. Thus the number captured by the net was equal to the average number caught by the traps.

From the above results it may be concluded that molasses bait traps generally give a good estimate of the number of moths flying about an orchard. Bait traps apparently are not so attractive early in the season however, and may give a slight underestimation. Since the percentage of male moths captured by the net was so high, it is evident that the females remain close to the tree and do not fly in and out as freely as do the males. It was shown that molasses bait traps in scattered trees do not attract moths for any great distances, since the net captured as many dyed moths as each bait trap.

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The Castor-Bean Plant as a Source of Insecticides

H. L. HALLER and N. E. MCINDOO, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Interest in the use of the castor-bean plant, *Ricinus communis* L., for the control of insects has been stimulated in the last few years by publicity from several sources. In 1938 an Associated Press dispatch was circulated that grasshoppers died in large numbers after having fed freely on the leaves and stalks of the castor-bean plant. This statement was the basis of an article by Bear (1938). The extravagant claims made in this dispatch and in the article by Bear were refuted by Bare (1938), by Drake (1938), by the Oklahoma Agricultural Experiment Station (1939), and by others. Efforts were made by R. C. Smith (1939) and by Spain (1940) to settle the controversy. Independently they found that grasshoppers, when given an opportunity, fed upon various common plants in preference to the castor-bean plant. There was no evidence that the castor-bean plant had any value for poisoning, repelling, or trapping grasshoppers or any other insect pest of crops. Smith even collected about 75 species of insects on the plant.

Soon after the publicity given the castor-bean plant for its supposed value in protecting crops, the development of a new insecticidal spray material extracted from the leaves of the plant was announced by Holzcker (1940). This development was stimulated by the necessity of finding uses for the by-products of the castor-oil industry to enable American oil to compete with the imported product. The original insecticide was a liquid mixture of plant extractives and lime-sulfur solution. More recently a dry powder has been made available. Results of controlled experiments with the insecticide have not yet been published, nor is the active insectidical constituent definitely known. Ricin, a toxic protein, and ricinine, an alkaloid, are known to occur in the seeds as well as other parts of the castor-bean plant. While it is known that both these compounds are poisonous to the vertebrates, little is known of their effect on insects. Hartzell & Wilcoxon (1941) found that ricin was not toxic as a contact poison against grasshoppers and that both ricin and ricinine were without effect when mixed with bran and fed to these insects. Siegler, Schechter, and Haller in current experiments have found ricin to be without effect but ricinine to be highly toxic to the codling moth larva, *Carpocapsa pomonella* (L.). In recent tests on houseflies, *Musca domestica* L., with samples of ricin and ricinine furnished by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine, John H. Fales[1] determined that a 1 per cent solution of ricin in water caused no mortality, and a 1 per cent solution of ricinine in acetone caused only 1 per cent mortality of the flies. As far as the writers know these are the only studies that have been made with these constituents of the castor-bean plant.The plant may, of course, contain other constituents that have insecticidal properties.

Publicity on the castor-bean plant as a source of an insecticide has also come from the use of N-isobutyl undecylene amide as a synergist with pyrethrum as mentioned by Hartzell and Scudder (1942). This amide, although relatively nontoxic when used alone, enhances the toxicity of pyrethrum insecticides. The amide is prepared from isobutylamine and undecylenic acid which is obtained on pyrolysis of castor oil.

It is possible that an insectidal principle is present in the castor-bean plant only under certain conditions with respect to variety, cultural practice, and environment. It would appear that the accepted use of the castor-bean plant as a source of insecticide awaits the isolation, identification, and methods of analysis of the specific substance or substances toxic to insects.

A review of the nearly 50 published papers on the insecticidal uses of the castor-bean plant has been prepared by the junior writer.—7-12-43.

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[1] The writers thank Mr. Fales for the use of his unpublished results.

Leafhopper Resistance Among the Bean Varieties[1]

J. S. McFARLANE and G. H. RIEMAN, *University of Wisconsin, Madison*

In a preliminary study at Madison, Wisconsin in 1941 twenty-seven varieties of snap and lima beans were tested for resistance to the potato leafhopper, *Empoasca fabae* Harris. Varietal differences in susceptibility have previously been reported by DeLong (1938).

In this study the twenty-seven varieties were planted in five foot rows and were replicated four times. Readings for leafhopper injury were made when the most susceptible plants were severely stunted and the leaves severely curled and puckered, but before any appreciable injury occurred on the most resistant variety. The varieties were assigned to one of five classes depending on the severity of the injury through the use of a technique similar to that used in classifying potato segregates for hopperburn resistance (McFarlane 1942[2]). The classification scheme used in this study follows:

Class 0—No injury.
Class 1—Plants slightly stunted. Leaves beginning to curl and pucker.
Class 2—Moderate stunting. Moderate leaf curling and puckering.
Class 3—Moderately severe stunting. Leaves moderately to severely curled and puckered.
Class 4—Severe stunting. Leaves severely curled and puckered.

Table 1.—A comparison of leafhopper injury class values and picking dates for twenty-seven bean varieties tested at Madison, Wisconsin in 1941.

Variety	Days from Sowing to Picking	Class Value for Each of Four Replicates			
Henderson's Bush Lima	65	0	0	0	0
London Horticultural	70	1	1+	2	1+
Idaho Refugee	64	2−	1+	2−	1+
Keeney's Stringless Green Refugee	70	2−	2	2	1+
Wisconsin Refugee	70	2	2−	2−	2
Hodson Wax	66	2	2	2−	2+
McCaslan	65	2	2+	2	2
Kentucky Wonder	65	2	3−	2+	2+
Sure Crop Wax	53	2+	3	2+	2+
South American No. 1	—	2	3−	3−	2
U. S. No. 5 Refugee	63	2	2	3	3−
Ideal Market	60	2	2+	3	3
White Kentucky Wonder	64	2+	2+	3−	3−
South American No. 3	—	2	3	3−	3−
White Creaseback	65	2	3	3−	3−
Asgrow Black Valentine	49	2+	3	3−	3
Pencil Pod Black Wax	55	3−	3−	3−	3−
Round Pod Kidney Wax	58	3	3−	3−	3−
French Horticultural	68	3	3	3	3
Red Valentine	52	3	3	3	3
Asgrow Stringless Green Pod	52	3	3	3	3
Giant Stringless Green Pod	53	3	3+	3	3
Bountiful	49	3+	3	3	3
Dwarf Horticultural	54	3	3+	3	3
Black Valentine	49	3	3+	3+	3
Improved Golden Wax	51	3+	3+	3+	3+
Tennessee Green Pod	50	4−	4−	4−	4−

The varieties showed a wide range in susceptibility to leafhopper injury as is indicated in table 1. The readings for the four replicates were in general very consistent, indicating that injury was uniform throughout the plot and that the method of measuring the injury was reliable. Henderson's Bush Lima showed outstanding resistance. A number of popular snap bean varieties were found to be susceptible. In general it can be said that the early maturing varieties are the most susceptible, whereas the late maturing varieties tend to be resistant.

This study proves that leaf hopper resistance exists in some of our common bean varieties and suggests the possibility of breeding for greater resistance and of combining this resistance with other desirable characters as found in the susceptible varieties.—4-10-43

[1] Contribution from the Wisconsin Agricultural Experiment Station. Paper No. 515 from the Department of Genetics.
[2] Unpublished thesis.

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Hibernation and Survival of the Locust Leaf-Miner

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The locust leaf-miner, *Chalepus dorsalis* Thun., hibernates between fallen deciduous leaves. The adult beetles cling to the lower side of a leaf as it lies on the ground. They are not next to the soil or leaves that are disintegrated but ones that still hold their shape when lifted. These leaves are often stuck together by moisture and fungus hyphae. Oak, especially the narrower types, and maple leaves seem to be preferred in this section. Most are found between the leaves that are loosely matted together and of a tan or yellow washed-out color. They have not been found in the upper layer of loose leaves that fell late in the fall. If the leaf cover is thin the beetles can be found in places where the leaves are lodged under brush or next to logs. They prefer a thick undisturbed mass of leaves. Well drained slopes or the higher spots about tree trunks or roots contain more beetles than lower spots. They seem to hibernate as close to the locust trees as suitable conditions are found. Some were found under locust trees but only when they were close to oak or other trees having heavy type leaves which had blown in numbers under the locust trees. In certain places near groves of locusts that had been heavily infested and where a thick leaf layer was not general, it was possible to sift from 4 to 24 beetles from leaf accumulations in a 3-sq. ft. area.

The emergence of the locust leaf-miner extends over several days, depending to some extent on the exposure of the woods. In 1943 the first beetles were found on leaves of apple trees growing near a grove of locusts on a ridge on May 5. That day however beetles could be found in numbers in the leaf mold in woods with a north slope. However none could be found on the nearby southern slope where there had been plenty the week before.

After two warm days the beetles were numerous on apple leaves. 1 to 8 could be seen on a single leaf feeding on the upper surface. This activity continued on apple for two weeks. They were found feeding on locust also but not in such large numbers. Beetles were seen resting on persimmon, summac and red maple leaves.

Wire screen cages for survival tests containing oak and maple leaves were prepared in December. The beetles were placed on these leaves and the cages put among the leaf litter under some bushes in a p'ace shaded by trees in the afternoon and by a building in the morning to simulate forest conditions. Two cages with 90 and 201 beetles were placed on December 1 and January 4. A third cage started December 1 with 50 beetles had 48 added on December 12. Records were made on March 29 with a survival of 88.23 per cent in the first cage, on May 3 with 92.27 per cent in the second, and of May 5 with 88.3 per cent in the third cage.—6-25-43.

Relation of Fertilizers to the Development of the Cotton Aphid in 1941 and 1942

R. L. McGARR, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Previous studies by the writer (McGarr 1942) indicated that the use of nitrogen in fertilizers on land planted to cotton stimulates the development of the cotton aphid, *Aphis gossypii* Glov., when followed by applications of calcium arsenate. The more general use of nitrogen from various sources in recent years is undoubtedly an important factor in the increased seriousness of the damage caused by the cotton aphid. The tests at State College, Miss., in 1941 to determine the relation of nitrogen in fertilizer to the abundance of the cotton aphid were repeated at the same location in 1942. In these tests the build-up of the aphids on cotton treated with calcium arsenate dust and fertilized with materials containing different amounts of nitrogen but fairly constant amounts of phosphoric acid and potash was compared with the build-up after treatments with calcium arsenate dust and applications of fertilizer containing only phosphoric acid and potash, treatments with calcium arsenate dust alone, application of fertilizer alone, and also after no insecticidal treatment and no fertilizer.

The fertilizers were factory-prepared and were applied at the rate of 600 pounds per acre just prior to the planting of the cotton, as in 1941. There were six replicates of each treatment, three of which were located in each of two fields on the same farm. The location of the plots, their size and arrangement, and the procedure followed in making the various records were the same as those used in the preceding year.

Applications of calcium arsenate dust were made at 5-day intervals beginning on July 10, which was about the time the first blooms appeared on the cotton. Six applications were made by August 4, all of which were considered effective, as none were washed off by rain within 24 hours. The average amount of calcium arsenate applied per acre per application ranged from 6.3 to 6.9 pounds.

The first infestation records for the aphid and the boll weevil were made on the day of the first dust application. Six additional aphid records were made in field 1 and five in field 2 after dusting had been started. Two records were made for the boll weevil. No importance was attached to the boll weevil damage, however, as the seasonal infestation in the plots receiving different treatments ranged only from 0.5 to 2.4 per cent. No yield records were made in the plots.

The treatments used and the maximum and seasonal aphid infestation records for 1941 and 1942 are shown in table 1.

The trends in both the maximum and average aphid populations in 1942 were similar to those in 1941, indicating again that the use of nitrogenous fertilizer resulted in a definite increase in aphid population when the cotton was dusted with calcium arsenate, but no appreciable difference was observed when calcium arsenate was not used. The increase in the number of aphids after dusting with calcium arsenate was significant in all cases, and where both nitrogenous fertilizer and calcium arsenate were used the aphid population was correlated with the percentage of nitrogen in the fertilizer.—6-1-43.

Table 1.—Cotton aphid infestations following different treatments in 1941 and 1942, the data given being the averages for six tenth-acre plots.

Treatment		Active Fertilizer Ingredients (Per Cent)						Aphids per Square Inch of Leaf Area (Number)			
		Nitrogen		Phosphoric Acid		Potash		Maximum		Average	
Fertilizer	Calcium Arsenate	1941	1942	1941	1942	1941	1942	1941	1942	1941	1942
Present	Present	—0	—0	8.15	8.60	4.19	4.34	34.28	16.64	6.75	9.02
Present	Present	2.29	2.62	8.60	8.43	3.49	4.42	45.08	17.94	8.34	9.52
Present	Present	4.08	3.82	8.15	8.50	4.17	3.56	48.48	22.63	8.88	11.67
Present	Present	6.53	6.22	10.65	9.48	3.60	4.03	55.66	28.84	9.76	15.01
Present	Absent	6.53	6.22	10.65	9.48	3.60	4.03	5.75	4.49	1.07	2.22
Absent	Present	—0	—0	—0	—0	—0	—0	30.49	13.33	6.05	7.28
Absent	Absent	—0	—0	—0	—0	—0	—0	4.59	3.91	.91	1.97
Minimum significant difference at 5 per cent level										2.36	1.99

[1] In cooperation with the Mississippi Agricultural Experiment Station and the Mississippi State Plant Board. In 1942 L. Q. Glasgow and M. W. Fondren assisted in making the field records. Analyses of the fertilizers were made through courtesy of the Mississippi State Department of Agriculture and the State chemist. Thanks are due R. C. Gaines for making the statistical analysis.

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Sulfur Dust and Hop Aphids

C. E. YARWOOD,[1] *Division of Plant Pathology, University of California, Berkeley*

Although pentathionic acid, which was considered as possibly the active constituent in sulfur used as a fungicide, was reported[2] to be about one third as toxic to aphids as was nicotine sulfate, sulfur is apparently not generally recognized or used as a control for aphids. Sulfur dusts and sprays are widely used for the control of powdery mildew of hops in England and in New York, where aphids are also important pests, but no effect of these sulfur applications on hop aphids has been noted.[3]

Also, Mr. Don Martin, an apple grower, has observed that rosy apple aphids, *Anuraphis roseus* Baker, were less severe on sulfur-dusted than on non-dusted apples. Observations of apple growers indicate that the "kill" of apple aphids following the use of sulfur dust is greatest in periods of hot weather. The apparent control of hop aphids by sulfur dust in the Santa Rosa district of California, and the apparent lack of control from sulfur in New York State and in England might also indicate that high temperatures or some other environmental factor was associated with the aphicidal effect of sulfur in California. Opposite hop leaves bearing about 100 aphids per leaf were cut and placed in vials of water, the number of aphids on each leaf was counted, one leaf of each pair was dusted with *Flotox* sulfur, the pairs of leaves were placed at a series of controlled temperatures in the dark for about 12 hours, and the number of living aphids again counted. On the control leaves many aphids were produced by viviparous females during the test period, and therefore the second count was frequently higher than the first. The count of aphids on each leaf after treatment and exposure to the test temperatures is expressed as the per cent of the original number on that same leaf before treatment. In three tests the average per cent survival of aphids on control and dusted leaves respectively was 103 and 91 at 16° C., 113 and 78 at 25° C., 111 and 21 at 31° C., 110 and 14 at 34° C., and 10 and 0.2 at 38° C. These results support the observations of growers that the kill of aphids on apples and hops with sulfur is related to high temperatures.—7-12-43.

Table 1.—Effects of sulfur dust on the numbers of hop aphids.

Description of Plots	Replications of Treated and Control Plots	Not Sulfured		Sulfured	
		Leaves Counted	Aphids per Leaf	Leaves Counted	Aphids per Leaf
1942 Santa Rosa, Applications May 20, 27, June 7, 13	2				
Counted June 13		11	31	11	1.1
Counted June 25		10	13	10	0.9
Berkeley, Application July 10	3				
Counted July 14		13	35	13	19
1943 Santa Rosa, Ranch 1, Applications May 4, 11, 19, 26, June 2, 9	4				
Counted May 19		19	4.9	17	2.6
Counted May 26		23	8	21	0.14
Counted June 2		48	18	48	0.06
Counted June 9		41	16	42	0
Santa Rosa, Ranch 2, Applications May 12, 26	2				
Counted June 2		10	1.5	10	0.1

As a result of studies[4] indicating that sulfur dust might be of value for the control of hop downy mildew, *Pseudoperonospora humuli* Miy. and Tak., a grower, Mr. Ben L. Steele, dusted about 100 acres of hops in the Santa Rosa district several times during May and June of 1938, 1939, 1940, and 1941. Downy mildew was not severe during these years in this district, and it is not certain that these applications were of value in downy mildew control. However, Mr. Steele observed that during these years aphids, *Phorodon humuli* Schrank, were less abundant on his hops than on his neighbor's hops which were not dusted with sulfur, and less abundant than in previous years on his own property.

Because of apparent differences counts were made of aphids on hop mildew experimental plots in 1942 and 1943, during which years the disease did not develop into a serious problem. Flotox dusting sulfur was thoroughly applied with a knapsack duster, and though the dosage was not measured, it was probably about 20 pounds per acre per application. Results of counts presented in table 1 indicate that on vines dusted with sulfur the average numbers of hop aphids were reduced to about one fifth the numbers on the unsulfured vines. Excluding the results from a single application in Berkeley where the temperatures are lower than where the other tests were conducted, there were only about one nineteenth as many aphids on the sulfured as on the non-sulfured leaves.

[1] The writer expresses his appreciation to Dr. E. O. Essig for identification of the hop aphids and to Dr. G. F. MacLeod for examining the experimental plots and for aid in preparation of this report.

[2] Liming, O. Neal. Phytopath. **23**: 153–74. 1933.

[3] In a letter of July 8, 1942, Dr. R. O. Magie of the New York Agricultural Experiment Station, Geneva, writes, "Circumstantial evidence in this State would not suggest any marked degree of aphid control with sulphur."

[4] Yarwood, C. E. Phytopath. **27**: 931–41. 1937.

JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 36 August, 1943 No. 4

Post-War Entomology

IN THE MIDST of war the nation is considing the local, national and international adjustments which will be necessary when the war is won and we are free once more to restore peacetime activities. Such considerations bring out the fact that we will never be able to restore conditions which have been disrupted by the war; that war, destructive as it must be, is still a period of abnormally rapid progress in many lines. After the war it will be incumbent upon those activities which have been static or even retarded in their normal progress, to catch up with the many lines of endeavor which have made wartime progress.

Only in certain of its phases has entomology been stimulated to unusual progress by the war; in others its normal progress has doubtless been somewhat held back so that, in all probability, entomology, as well as many other professions, will require unusual efforts if it is to catch up and maintain pace with many other occupations.

The period immediately following any war is difficult in many ways because of the serious readjustments of personnel and industry which necessarily attend the demobilization of armies. But for the same reasons it is probably the time when it is easiest to effect large-scale changes in formerly fixed practices. And perhaps the activities which can most easily be initiated in such a period are those which require large-scale organization and concerted action involving many individuals.

Such a period might well be particularly favorable for the establishment of entomological practices which have been hitherto impossible, not entomologically, but because of the human reaction to the suggestions. Entomologists, therefore, no less than other groups, may well concern themselves now, not only with the study of the problems which affect the nation and the world but also with the problems and opportunities which will be of particular interest in their own field. We must not lose sight of our primary concern—winning the war, but we should at the same time give thought and group consideration to the post-war period and to our professional interests in that period.

Concrete suggestions are doubtless premature at this time just as they may be in the international field. But if we do not at least consider *all* possibilities beforehand we may overlook some of the most practical and important. So we will venture to suggest a few possibilities in the hope that others may do the same and that all suggestions may be discussed at such meetings, formal and informal, as we are able to arrange before the establishment of the peace.

First, we may take it for granted that entomology will make immediate use of the advances in aviation. The returning fliers, many of them already trained in entomology, will see to that. But it is now high time for us to give thorough study to the insect control programs which can be most benefited by wider use of the airplane. Modification of our insecticides to perfect them for airplane delivery; aerial fumigation, application of the method to relatively small-scale operations as well as to the larger ones and particularly the perfection of the method to permit control of the many forest insects which have been, so far, relatively unchecked by man all may be mentioned.

Chemical entomology will also benefit. Certainly many new substances developed in connection with war activities must have some value to the entomologists. Here, once more, men now in the army who are peacetime entomologists may be expected to take the lead and vastly to extend the possibilities of insect control by chemicals.

Insect control programs involving organization and personnel exist and should be given attention. The actual or practical, temporary or permanent, extermination of several of our important pests is possible but will require large-scale sup-

port and organization. No entomologist is likely to question the *possibility* of extermination of the horse bots or cattle grubs in the East although some may question the practicability of such a project. But if this is ever to be practical it will be in the immediate post-war period. Other insects could readily be added to this list. Zoning of areas where certain crops are grown, cotton for instance, so that there might be a no-cotton area in successive years in the different zones and the boll weevil reduced to harmless numbers for succeeding years, might be considered. A long-time rotation scheme which would provide practically all the boll weevil control necessary might be worked out. Such programs might well be considered for other insects and other crops.

Another suggestion deals with a phase of entomology which has never been adequately considered. This is the application of the information on insect control which is developed through research. An example of the needs along this line is furnished by household insects. We can give fairly adequate information on how such pests may be controlled. Possibly we recommend fumigation. Then we tell our client that he can't fumigate because the operation is dangerous and requires special training and equipment. But in most instances we cannot refer him to a source of such service because it does not exist. To a degree this same situation arises when we discuss with the city dweller the control of insects on ornamentals. Should not the entomological profession take an active part in the development of commercial entomology? We have made a beginning by a little active cooperation with the Pest Control Industry; but this industry is entirely insufficient for the needs of the people. Smaller places do not have the benefit of it at all and many larger cities could use much more than they have. We might well give considerable thought to the provision of entomological services, on the basis of private industry, in our post-war world.

Extension entomology, seen as a function which is primarily educational, should be stimulated and made more adequate; but private enterprise should be encouraged to assume many of the functions which the public has come to expect from the extension personnel.

The entomologist should be represented on every public health organization. No really civilized community should tolerate the housefly and kindred insects and their elimination probably should be expected as a result of cooperation between entomologists and public health authorities. Our post-war program should not neglect this.

State and regional planning groups have been operating already for some years. Entomologists should be represented on such Boards or Committees. They may well help guide agriculture in such a way that the dangers from insects to crops will be greatly lessened.

Suggestions might be multiplied but the ones given may promote the offering of substitutes or additions and this is the primary purpose of this article. Certainly entomologists must have their program ready for immediate initiation at the end of the war and this program should be as ambitious as it can be made even if it seems to go beyond what we have been in the habit of considering practical.

SERVICE NOTES

M. L. Anderson, Tallahassee, Florida, is now an Ensign, USNR, stationed at the Naval Medical Center, Bethesda, Maryland.

Harold R. Yust, Whittier, Calif., is now Lt. (j.g.) USNR, Stationed at Naval Medical Center, Bethesda, Maryland.

J. G. Watts, Edisto Experiment Station, Blackville, S. C., is now a Major, Sanitary Corps, stationed at the School of Military Government, Charlottesville, Virginia.

H. S. McConnell, College Park, Maryland, is now 1st Lt., Sn.C., and is stationed at Camp Forrest, Tenn.

W. D. Reed, formerly of the Tobacco Insect Laboratory, Richmond, Va., is now 1st Lt., Office Chief of Engineers, Room 2110 New War Bldg., Washington, D. C.

H. H. Shepard, St. Paul, Minn., is now Senior Industrial Specialist, Chemicals and Fertilizers Division, War Food Administration, U.S.D.A., Washington, D. C.

OBITUARY

Wesley Pillsbury Flint, 1883-1943

Wesley Pillsbury Flint, national authority in economic entomology and chief entomologist of the Illinois Natural History Survey and of the Illinois Agricultural Experiment Station, died suddenly from a heart attack at his desk, in Urbana, Illinois, Thursday morning, June 3.

Professor Flint was 60 years old, having been born at South Hampton, New Hampshire, May 4, 1883. After completing two years at the University of New Hampshire, he was with the Massachusetts Gipsy Moth Commission and the H. L. Frost Company. In November, 1907, he became connected with the office of State Entomologist of Illinois, one of the predecessors of the Illinois Natural History Survey. When in 1917 Stephen A. Forbes, the last official State Entomologist of Illinois, was named to head the Survey, Mr. Flint became Economic Entomologist of this organization, taking over many of the duties relating to economic entomology previously performed by Professor Forbes. Later he became

Chief Entomologist of the Survey and in 1930 he was named also Chief Entomologist of the Illinois Agricultural Experiment Station with the title of Professor. He held both positions at the time of his death.

Professor Flint was a national figure in entomology. He was notably active in the American Association of Economic Entomologists, serving as president and for many years an active member of the Association's major committees, where he served with enthusiasm and always gave of his abundant knowledge to the problems affecting the Association and the science of entomology. Flint was also a fellow of the Entomological Society of America and the American Association for the Advancement of Science, and a member of the Illinois State Academy of Science, Sigma Xi and Gamma Sigma Delta. He was a member of the Board of Governors of the Crop Protection Institute; chairman of the Century of Progress Committee on Entomological Exhibits, and held many other committee and project assignments. Industry in following through on assignments, and giving them the utmost in thoroughness, was one of Flint's outstanding characteristics.

Professor Flint was a national authority in economic entomology, especially in the field of orchard and field crop insects, and was author of many important scientific and economic papers, as bulletins and in trade and scientific journals. With Prof. C. L. Metcalf, he was co-author of *Destructive and Useful Insects*, one of the outstanding books in economic entomology. Also, he was co-author of *Insects, Man's Chief Competitors*, a popular book sponsored by the Century of Progress Exposition.

During his 35 odd years in Illinois, Flint became a leader in University and State affairs. His council and advice were sought by farm organizations throughout the state of Illinois and by his colleagues in many north central states. He was practical in his views and his opinions were highly respected because of their practical implications. He was a friend and wise counselor to the men who were responsible to him in the Section of Economic Entomology of the State Natural History Survey. To a considerable degree, Flint's strength as a practical entomologist had its foundations in his friendly and helpful character.

Perhaps we can do no better, in closing this tribute to our life-long friend, than to quote statements by his two superiors.

Dr. Theodore H. Frison, chief of the Illinois Natural History Survey, says: "The unexpected passing of Professor Flint comes as a deep personal loss and as an even greater loss to the Natural History Survey and the agricultural interests of the State and the nation. Professor Flint, who came to the Survey as an entomologist in 1907, advanced rapidly in his profession until at the time of his death he was recognized as one of the most outstanding economic entomologists in this country. He was simple in his tastes, direct in his manner, and highly practical in his application of entomology in the service of agriculture. For these reasons he was immensely popular with the farmers and agricultural advisors throughout the state. His loss will be keenly felt by all of us for a long time, especially when we are in the midst of a war effort agricultural production program in which advice and information such as he was able to offer are so essential."

Dean H. P. Rush of the College of Agriculture writes: "Professor Flint's contribution to midwest agriculture has been outstanding. He had an unusual ability to put scientific information into terms that the public could understand and use. His advice on entomological problems was consistently sought, and no man on the campus enjoyed a larger measure of public confidence than Professor Flint. He was highly esteemed as a man by his colleagues. Thousands of people engaged in all branches of agriculture throughout the midwest held him in high personal regard."

Professor Flint is survived by his wife, Florence Bell Wright Flint and a sister, Miss Mattie Flint of Newburyport, Massachusetts.—J. J. DAVIS.

REVIEWS

A Classification of Larvae and Adults of the Genus Phyllophaga (Coleoptera: Scarabaeidae. By Adam G. Böving, Associate in Zoology, Smithsonian Institution, Washington, D. C. Memoirs of the Entomological Society of Washington, No. 2.

Workers in entomology generally should welcome this contribution, which presents the results of an intensive investigation of the classification of larvae and adults of the genus *Phyllophaga*. A ready means for the specific determination of larval stages is particularly useful in the present genus, which is composed mainly of forms with life cycle too protracted for rearing the adult for any reasonably prompt study or identification.

This well-printed 96-page volume is illustrated by six text figures and twelve plates of excellent detailed drawings of the important morphological structures used in classification of both larvae and adults. The subject is considered under two main headings, viz., morphological and systematic.

Under the morphological phase of the study detailed descriptions of selected body structures in mature and first stage larvae are given with carefully executed drawings of the same. These contribute materially to a better understanding of the highly technical subject under consideration. Some additional new terms, referring mostly to the structural details of the male genitalia are listed and defined. As a further aid to the average worker a glossary of terms applied to the structural parts of the larvae and adults treated in the paper is appended in alphabetical order for ready reference.

The systematic discussion deals first with the interrelationship of the genera of Melolonthini, the position of *Phyllophaga* in the tribe and the classification of species belonging to the genus. This is followed by analytical keys; one to the known larvae of closely allied genera, one to the 21 larval groups to which the species have been assigned, and one to the known larvae, including 60 species or nearly one-half of the forms recorded from the United States. Perhaps the most significant conclusion resulting from this investigation is that specific larval and adult classifications in *Phyllophaga* agree closely even though each is based upon entirely different structural characters. The author points out that a progressive development of the species can be recognized only in the adults, mainly on the forma-

tion of the male genitalia; nevertheless by the use of different combinations of characters the larvae have been assigned to groups which conform with the adults and therefore appear to express natural relationship. The 21 groups of the revised classification are defined by a combination of larval and adult characters and the specific relationships as expressed by these groups call for considerable readjustment in the hitherto generally accepted groupings published by Dr. Horn over a half century ago. Students interested in *Phyllophaga* will find this volume indispensable and it should prove a useful reference to all workers interested generally in morphology and taxonomy of insects.—6-29-43.

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A. F. BURGESS RETIRES FROM THE BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

On August 5, 1943, a testimonial dinner in honor of Mr. Albert F. Burgess, who will retire on account of statutory limitations in the near future, was arranged by the Division of Gypsy and Brown-tail Moth Control of the Bureau of Entomology and Plant Quarantine and held on that date at the Weldon Hotel, Greenfield, Massachusetts.

In spite of the difficulties of travel ninety-five members of the office and field force, Bureau, State officials, and friends with members of their families, attended. Dr. P. N. Annand, Chief of the Bureau, presided at the dinner and in behalf of the Bureau expressed his appreciation for the work and long service of Mr. Burgess on the gypsy moth project, and also as President of the American Association of Economic Entomologists his high regard for the work which Mr. Burgess performed for the Association for many years.

At the close of the speaking Mr. H. B. Dalton, Administrative Officer, who has been associated with the Federal gypsy moth work since operations began in 1906 presented Mr. Burgess with a gift in behalf of those present and others who had been unable to attend in appreciation of his thirty-six years of service in the Bureau and the friendly relations which have existed between the operating force and the States where the work has been done. A bound volume of letters and statements signed by more than two hundred State and Bureau officials and fellow-workers on the gypsy moth project was presented to Mr. Burgess by Mr. R. A. Sheals, who succeeded Mr. Burgess in charge of the Division of Gypsy and Brown-tail Moths Control. Comments concerning the work and appreciation for the helpful support in the past by those present and all associated with it were made by Mr. Burgess before the close of the meeting.

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